**Naval Surface Warfare Center**
**Carderock Division**
West Bethesda, MD 20817-5700

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Total Ship Systems Directorate

Technical Report

# SEABASING INNOVATION CELL 'TRANSFER OF GOODS AT SEA'

# FINAL REPORT

by

Mark Selfridge

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A Center for Innovation in Ship Design study was conducted to investigate the naval architectural implications of transferring cargo and personnel in a sea base environment. Emphasis was placed on rough water operations. The team developed four advanced concepts to enhance transfer of goods at sea and completed preliminary assessments of their performance within a seabase. The four concepts are an Intermediate Transfer Station, a Deep Water Stable Craneship, a Seabase Hub, and an Advanced Logistics Delivery System. In addition, a number of seabase enabling technologies including selective offload, re-configurable spaces, seakeeping, materiel management systems, a cargo dispenser concept, an air pallet cargo stowage concept, and spiral ramp concepts were investigated to enhance the understanding of key design drivers and to highlight naval architectural issues.

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The content, however, is the collective input of the individual team members.

# 1 Executive Summary

## 1.1 Background

1.1.1 The Center for Innovation in Ship Design (CISD) at the Naval Surface Warfare Center - Carderock Division (NSWC-CD) were tasked by the Chief of Naval Research (CNR) Rear Admiral Jay Cohen, to investigate Seabasing as it relates to Seapower 21 and the United States Navy Transformation.

1.1.2 At Carderock, a multi-disciplinary team (see Annex B) formed in late February 2003 and reported on 30 May 2003; a period of 14 weeks. The team was led by Mark Selfridge, a Naval Architect from the United Kingdom Ministry of Defense (MoD) currently on a two year exchange at NSWC-CD.

1.1.3 This report describes the work undertaken and the conclusions drawn.

## 1.2 Scope of Work

1.2.1 Current uncertainty with respect to what a seabase should be (e.g. a collection of ships or a very large floating warehouse), lead the team to focus on a known problem - transfer of materiel at sea. In particular the team set out to determine the naval architectural issues and the factors limiting the transfer of materiel at sea.

1.2.2 The team were required to develop and assess a range of concepts to improve the logistics capability of a seabase. In total, fifty concepts were identified, however resources limited the number to four for development and assessment. In addition, the team were requested to identify the high risk (technology gap) aspects of the concepts that would require development to fully exploit the capability of the concept.

## 1.3 Concepts & Enabling Technologies

1.3.1 The four concepts were;

- Intermediate Transfer Station (ITS)
- Deep Water Stable Craneship
- Seabase Hub
- Advanced Logistics Delivery System (ALDS)

1.3.2 These concepts were developed and assessed to determine their performance within a seabase. In addition, the team identified a number of seabase Enabling Technologies including;

- Selective Offload
- Re-configurable Spaces
- Seakeeping
- Materiel Management System
- Dispenser Concept
- Air Pallet Concept
- Spiral Ramp Concepts

These were investigated to enhance the understanding of key design drivers and to highlight the naval architectural issues.

1.3.3 For sizing and materiel handling purposes, the out-load for a Marine Expeditionary Brigade (MEB) was used in terms of personnel, dry cargo and vehicles.

1.3.4 Four global seabasing issues were identified as well as the particular features of the concepts that tackled these issues directly.

## 1.4 Way Ahead

1.4.1 The Selective Offload and Re-configurable Spaces work packages are being further developed under funding from PMS325 from the Military Sealift Command (MSC)

1.4.2 The team briefed Rear Admiral Jay Cohen at NSWC Carderock on Thursday 12 June 2003. Rear Admiral Cohen requested the following;

- Preparation of articles for engineering journals
- Presentations and briefings be given to wider community
- Identify and conduct follow-on tasks to further develop particular concepts and enabling technologies and to assess any associated risk

# 2 Introduction

## 2.1 Sponsor

2.1.1 The Center for Innovation in Ship Design (CISD) at the Naval Surface Warfare Center - Carderock Division (NSWC-CD) were tasked by the Chief of Naval Research (CNR) Rear Admiral Jay Cohen, to investigate Seabasing as it relates to Seapower 21 and the United States Navy Transformation. Rear Admiral Cohen's visionary depiction of seabasing is included at Annex A. A key feature is the large floating warehouse / facility where ships will med-moor to enable efficient transfer of materiel at sea.

2.1.2 At Carderock, a multi-disciplinary team (see Annex B) formed in late February 2003 and reported on 30 May 2003; a period of 14 weeks. This report describes the work undertaken and the conclusions drawn.

## 2.2 Scope of Work

2.2.1 The initial work specification found in Annex C, called for a functional analysis, system synthesis and a technology road map. Uncertainty over the definition of a seabase lead the team to focus on the transfer of 'goods' at sea and in particular to identify the naval architectural issues limiting at-sea transfer of vehicles, equipment, people, liquids, containers and pallets. It was clear that the transfer of goods would remain fundamental to the efficiency and sustainability of a seabase regardless of what a seabase turns out to be.

2.2.2 Having identified the naval architectural issues and those factors limiting current at-sea transfer, the team were required to develop and assess the performance of a range of concepts to improve the at-sea transfer of cargo and to identify any technology development requirements to fully exploit these concepts.

## 2.3 Approach

2.3.1 The team identified the naval architectural issues and factors limiting at-sea transfer through formal and non-formal functional analysis. Discussions, meetings and interviews were held with academia, industry and a wide range of internal and external experts. In addition, the team used the Internet, viewed full scale and model test video footage and reviewed related reports and studies. A number of conferences were attended and visits to commercial facilities to view relevant systems were undertaken.

## 2.4 Functional Analysis

2.4.1 A functional analysis was required to provide a definition of the system, (i.e. the logistics chain) and to eliminate gaps in the team's understanding of the problem. To initiate the concept development phase a number of assumptions had to be made with respect to the boundary within which the team should focus their efforts. Figure 1. illustrates the factory/fort to foxhole concept which is the complete logistics chain highlighting the boundary within which the team worked;

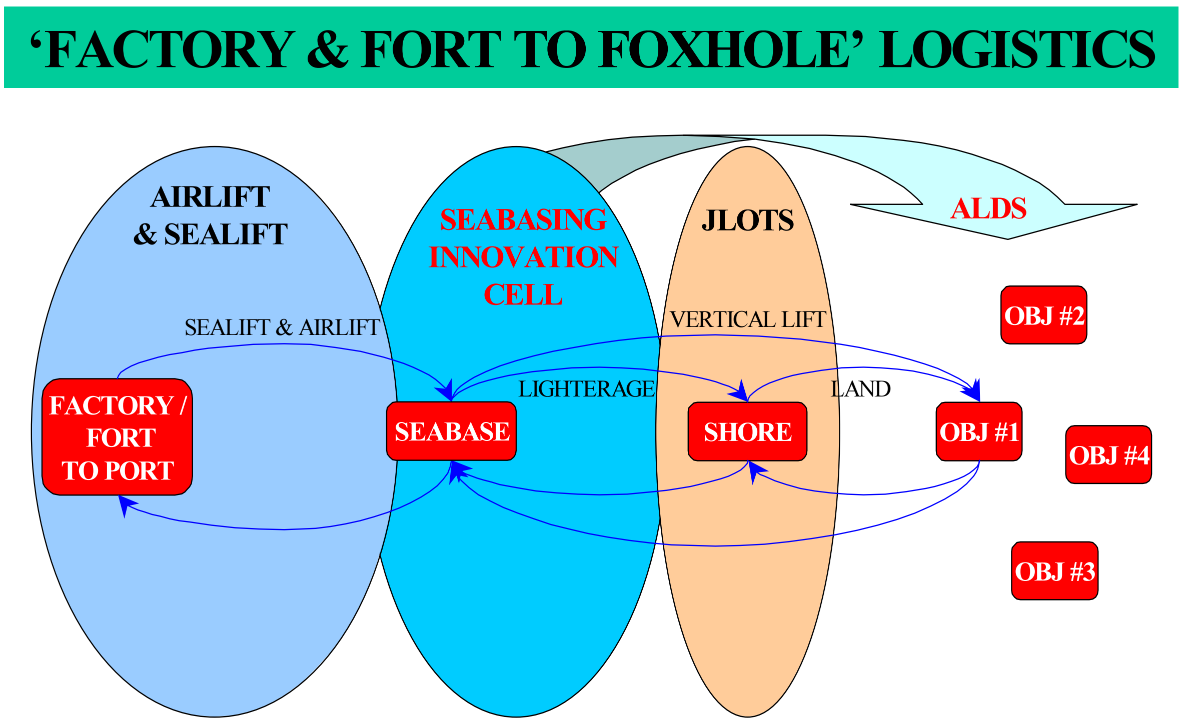



Figure 1. Seabasing within the Logistics Chain

2.4.2 The seabase was considered to have a 'supply' side that would interface with large ships such as the Large Medium Speed Roll-on/Roll-off (Ro/Ro) LMSR, containerships, etc. and a 'demand' side that would interface with lighterage from the Joint Logistics Over The Shore (JLOTS) environment to supply the shore. This was driven by the teams understanding of concepts such as Ship to Objective Maneuver (STOM), Operational Maneuver From The Sea (OMFTS) and visibility of the US Marine Corps Seabasing Concept of Operations and the Maritime Pre-Positioned Force Future (MPF(F)) ship designs.

2.4.3 An unfriendly coastline could dictate that a seabase has to locate up to 200 nautical miles (nm) offshore. This assumption lead the team to focus on deep water solutions for transfer of goods as opposed to the shallow water operations conducted by JLOTS.

2.4.4 The team identified five main seabasing phases as follows;

- **At-sea Arrival & Assembly**…….of the seabase
- **Initial Delivery & Selective Offload**…..…of forces ashore
- **Indefinite Sustainment**…….of the forces ashore
- **Reconstitution**…….of people and materiel
- **Maintenance & Sustainment**…..…of other seabased platforms

The team did not consider the first and last phases in this study. The assumption was that the seabase had arrived and that the maintenance and sustainment are required even if the seabase is not there. The deep water solutions developed, focused on the initial delivery and selective offload, sustainment and reconstitution phases exclusively.

2.4.5 Fifty plus concepts were identified through brainstorming. Grouping allowed some high level study to occur to aid down-selection of the three preferred concepts for development and assessment and subsequent identification of the technology shortfalls.

2.4.6 During a progress meeting with the sponsor, Admiral Cohen requested that the team give some consideration to concept(s) that looked towards the 2020 timeframe and encouraged the team to think more innovatively. Given limited resources, the team included a concept known as the Advanced Logistics Delivery System (ALDS) ref.[31] which was developed by a previous innovation cell at Carderock. ALDS bypasses the JLOTS environment by projecting gliders from a ship to an altitude from which they glide (over the littorals) to their target destination.

2.4.7 The team developed a simple cost model to compare the costs (personnel and fuel) of delivering a full load of supplies via a Landing Craft Utility (LCU2000) to troops 30 miles inland by ALDS, truck and various vertical and/or short takeoff and landing (V/STOL) aircraft (e.g. Huey, CH53 and V22 Ospreys). The inclusion of ALDS expanded the total number of concepts being developed to four.

## 2.5 Concepts

2.5.1 The four concepts developed by the team were;

- A deep water stable craneship
- An intermediate transfer station
- A seabase hub
- An advanced logistics delivery system

2.5.2 The seabase hub is supported by generic enabling technologies namely, selective offload and Re-configurable spaces. These areas were also the focus of other ongoing PMS 325 funded efforts under Strategic Research & Development Program. The opportunity to collaborate here was particularly fortunate.

2.5.3 The aim was to develop concepts and then to assess their individual performance sufficiently to;

- Ensure a coherent understanding of their design drivers and characteristics
- Determine and explore their associated naval architectural issues
- Provide recommendations for future research

Each concept is discussed in detail in this report.

2.5.4 Other seabased enabling technology areas were investigated and include a seabase materiel management system, seakeeping and selective offload concepts namely a dispenser concept, an air pallet concept and various spiral ramp concepts.

## 2.6 Cargo

2.6.1 To develop the concepts an understanding of the cargo types and quantities was required. The team identified 18 cargo types and considered a range of cargo characteristics, namely transfer method, rate of transfer (high, medium, low), hazardous, self mobile and any personnel safety issues. A matrix was constructed to tabulate the cargo types and corresponding cargo characteristics, see Annex P. This process identified the types of cargoes but provided no real indication of the 'preferred' transfer method nor the problems associated with their transfer at sea.

2.6.2 To address the preferred transfer method, two further matrices were developed. These showed platforms types versus transfer methods. 11 transfer methods were identified and the platform types were split between ‘supply platforms’ and ‘delivery/extraction platforms’. Supply being to the seabase and delivery/extraction implying to/from the shore from/to the seabase. Both static and underway cases were considered and the matrices are included in Annexes Q & R respectively.

2.6.3 To address the problems associated with at sea transfer the team interviewed experts in the logistics arena (see Annex M & N for notes of meetings). In addition, the team watched videos of Underway Replenishment (UNREP) and Personnel transfer at sea in rough weather.

2.6.4 So, the team had developed an understanding of the cargo types, preferred or most common transfer methods and current at sea transfer problems. The volume and rate of materiel transfer were still outstanding. These areas were addressed through consideration of the daily needs of a Marine Expeditionary Brigade (MEB). This seemed particularly relevant given an option being investigated through the Maritime Pre-positioned Force (Future) MPF(F) ship designs is to spread the materiel demands of a MEB across six MPF(F) ships. A MEB consists of approximately 13,000 troops of which 6,800 would be put ashore. The troops ashore require 415 Short Tons (ST) / day of liquids (water and fuel) and 75 ST/day of dry classes of supply (i.e. food, ammunition, etc.), see Ref.[7]. The vehicle out-load totaled 357 vehicles ranging from High Mobility Multi Wheeled Vehicles (HMMWVs) to Medium Tactical Vehicle Replacement (MTVR) trucks to Engineering equipment vehicles, Howitzers etc.

2.6.5 While liquids (fuel and water) are by far the dominant cargoes, the team believe the transfer of these particular cargoes is well practiced and relatively straight forward when compared against other cargo types such as containers. Hence, the team decided to focus on the at-sea transfer of more ‘difficult’ cargoes, namely wheeled and tracked vehicles, containers, pallets and personnel. So, the dry stores and vehicle requirements of the MEB had been determined. In terms of sustainment it was deemed appropriate to assume a 30 day supply of these cargoes within the seabase to bound the volume of cargo in some way.

2.6.6 The Seabase Hub was sized around one sixth of a MEB to add some reality to the concept. Sustainment using a period of 30 days of supply (DOS) was deemed reasonable for a seabase hub given that its function is to provide indefinite sustainment and reconstitution of forces ashore and at sea. This phase is preceded by phase 2 which involves the initial delivery and selective offload of forces and materiel.

# 3 Seabasing

## 3.1 What is Seabasing?

3.1.1 One definition provided by the Center for Naval Analysis (CNA), ref.[16] is;

*"Seabasing is a deliberate, managed provision of all combat service support to forces ashore from ships offshore".*

3.1.2 This concept includes both the delivery of supplies and the provision of services from ships composing the logistics seabase to the combat units ashore by the most appropriate means, whether that be by air (helicopter) or by surface (landing craft). The definition is however very focused on sustainment to the detriment of delivery, reconstitution and reconfiguration.

3.1.3 Under Seapower 21, the intention with seabasing is to minimize the logistics footprint ashore thereby avoiding the need to establish large shore based storage and service areas. In doing so, the need for security of such sites is also removed. Once established, such sites are difficult to move and movement is resource intensive and slow limiting the response to any change in operational objectives. Seabased logistics is therefore particularly suited to those cases where the objective changes or moves, and where the overarching political situation or hostile nature of the coast does not allow a large build-up of logistics ashore.

3.1.4 Seabasing is in essence a transformational concept that significantly changes the projection, sustainment and protection of warfighting capabilities. Seabasing is more than just logistics - it allows the use of the sea as a maneuver space and in doing so capitalizes on the inherent protection that the sea provides to military forces.

3.1.5 The Falklands war is a real example of a seabasing. Following invasion of the Falkland Islands on 02 April 1982 by the Argentine armed forces, British amphibious counter attacks liberated the islands. The Royal Navy and Royal Fleet Auxiliary ships had to be augmented by sixty two ships taken up from trade (STUFT) all of which had to be converted in some way e.g. adding flight decks, communications fits, additional accommodation, etc. The geographical separation was some 8,000 nautical miles from home, to an inhospitable ocean, with no friendly port or host nation support. The STUFT ships were responsible for delivering over 8000 troops, 85 aircraft, 216 land rovers and 110,000 tons of freight and much more. Main engines had to be replaced at sea.

3.1.6 In light of the above, the team offer the following definition of Seabasing;

*"Seabasing intentionally minimizes the logistics footprint ashore by providing a mobile and responsive 'seabased iron-mountain' that is readily capable of efficiently packaging for the end-user and ensuring just-in-time indefinite sustainment and reconstitution of materiel."*

## 3.2 What is a Seabase?

3.2.1 A large floating warehouse - a mobile offshore base (MOB)? A collection of ships? All of the above? The reality is it doesn't matter as long as the seabase is able to project power ashore and can sustain that projection. The seabase needs the ability to alter the operational tempo quickly (i.e. should be flexible, scalable and responsive) and to actively embrace concepts such as Ship To Objective Maneuver (STOM) and Operational Maneuver From The Sea (OMFTS).

3.2.2 The seabase should be able to integrate;

- Joint Command & Control Ships
- Amphibious Forces (ESG)
- Carrier Battle Groups (CSG)
- Maritime Preposition Forces (MPF(F))
- Combat Logistics Forces (CLF)
- High Speed Sealift
- Lighterage Technologies

More importantly the seabase should enable effective and efficient logistics in order to enable effective warfighting. This implies understanding some specific characteristics.

## 3.3 Seabasing Characteristics

3.3.1 The following is a list of key seabasing characteristics;

- Interoperable (with own/allied forces and commercial vessels)
- Responsive and maneuverable
- Adaptable and scalable

- Secure
- Sustainable from the sea
- Dispersed

The character of the seabase changes if joint forces will ‘operate from’ the seabase rather than being ‘enabled by’ or ‘flowing through’ the seabase. The same is also true of allied forces.

## 3.4 Why Seabasing?

3.4.1 The recent war in Iraq provides some answers - lack of sufficient host-nation support, lack of ‘free’ air space over neighboring nations etc. Other reasons include;

- To counter area denial and anti-access strategies
- To enable a wide range of military responses
- To facilitate joint follow-up forces unencumbered by host-nation requirements
- To provide enhanced military options to decision makers
- To mitigate local/regional political sensitivities attached to a large US military presence

3.4.2 To assist the team in their understanding of seabasing, meetings were held with logistics experts. Copies of meeting notes are included in Annexes M & N.

# 4 Generic Supporting Technologies

## 4.1 General

4.1.1 The team focused on four supporting technology areas that are considered to be fundamental to seabasing. These are Selective Offload, Reconfiguration, Seakeeping and an effective Materiel Management System.

## 4.2 Selective Offload

4.2.1 Selective Offload is the ability to 'choose' a specific item of cargo (pallet, container, vehicle etc) and extract it with minimal or no disruption to other cargo as quickly as possible. The key words here are 'no disruption' and 'quickly'. That is, selective offload has two fundamental metrics - selectivity and time. The selectivity is enabled by space for access and so it is easier to quantify a so-called stowage factor than it is to quantify selectivity.

4.2.2 Here, Stowage Factor is defined as the;

*total footprint area of all vehicles divided by total cargo deck area including all access lanes/space and to the inside of the ships transverse frame structure*

An allowance of 3 feet was assumed to account for the depth of deep frames inboard of the side-shell. The Stowage Factors calculated here have been expressed in percentage terms.

4.2.3 In all cases here, 100% selective offload has been the design requirement. 100% selectivity 'bounds the problem' in the sense that it will result in the maximum area demands. Since 100% selectivity is more demanding, it will enhance identification of naval architectural issues and impacts. If its full impact is understood then decision making with respect to the degree of selectivity can be made from a more informed basis.

4.2.4 Here, 100% selectivity implies 'no moves - a particular vehicle', the slight exception is for angled parking where some reversing is necessary to get out of the parking space. Selective Offload has been investigated here primarily because it is a significant design driver. It was necessary to fully understand selective offload prior to designing the Seabase Hub. Selective Offload is discussed in Chapter 10.

## 4.3 Reconfiguration

4.3.1 The effectiveness of a seabase will be dictated by its ability to easily reconfigure to meet the specific demands of each of the seabasing phases as discussed in Section 2.4. The seabase needs the inherent ability to dynamically transform as the objective dictates. For example, the materiel demands for the initial delivery and offload phases will involve assembling and uniting troops with equipment. The demands, of this effort, on the seabase vary significantly from those for say sustainment or reconstitution. Hence, there is a need for the seabase to transform dynamically to respond to the specific needs of the particular phase.

4.3.2 One key phase of seabasing is 'indefinite sustainment' of the forces and equipment ashore, from the seabase. The lack of the 'iron mountain' ashore dictates the need to marry equipment and personnel at the seabase. Re-configurable spaces allow this to happen in an efficient manner. The team believe that reconfiguration, particularly an understanding of the whole ship impacts of Re-configurable spaces, enables a more flexible and adaptable design to be synthesized.

4.3.3 Re-configurable spaces might be used to accommodate troops in temporary accommodation, maintenance facilities, etc. The work here focused on identifying the ship systems inherent in large spaces such as cargo decks and holds. Then a 'wish-list' of possible functions was derived. The system requirements for these functions were determined at a high level where possible.

4.3.4 This allowed a matrix to be developed showing the system requirements against each 'Re-configurable space.' The idea being to enable rapid identification of those seabased functions best suited for Re-configurable spaces. Obviously those functions where their individual system requirements more closely matched the systems available, were most easily integrated into the seabase.

4.3.5 Of course, it is not just about system requirements - the ability to deploy and be 'packed-up' rapidly is a bonus. To this extent the team met with the Total Open Systems Architecture (TOSA) group at NSWC Carderock and discovered they have a database with some 1200+ entries of functions that can be containerized. Most of these containerized applications were intended for use ashore and did not address interface issues associated with use at sea inside ships. It is fair to state that almost anything can be containerized, however not all of these functions are necessarily a capability that a seabase needs or indeed would want.

4.3.6 Containerized solutions are one options but the team also looked at lightweight climbing equipment, namely portaledge, which is effectively a very lightweight bunk that can be carried by a climber and rigged on rock faces to allow the climber to sleep! These sorts of technology could be easily mounted from bulkheads / shipside in large cargo holds.

4.3.7 Reconfiguration is discussed at length in Chapter 11.

## 4.4 Seakeeping

4.4.1 Effective seabasing relies on good seakeeping characteristics of the vessels in the seabase. These in turn enable efficient at-sea transfer of 'goods' to ensure continued sustainment of forces ashore with increasing seastate. Hence, in the development of concepts to operate within the seabase it is fundamental to have good seakeeping analytic tools to allow rapid assessment and prediction of performance. The concepts developed here are intended to operate close to and with other large and small vessels, and hence the ability to model multi-body motions is fundamental. Effectiveness of analytic modeling can be greatly enhanced by physical modeling in a tank and full scale testing and trials.

4.4.2 NSWC Carderock have appropriate tools to model some of the concepts of interest. Seakeeping analyses were undertaken for;

- LMSR + Craneship + Lighter
- LMSR + Seabase Hub + Lighter (at stern of Seabase Hub)

In seastates 2,3,4,5 and 6. Polar plots for 360 degree wave headings at 15 degree intervals were produced. Motions in all six degrees of freedom (i.e. translational - surge, sway and heave and rotational - roll, pitch and yaw) were determined. In addition, for the craneship the motion of the crane tip (relative to the moving deck of the lighter) was determined for a number of seastates and headings. The specific seakeeping results for each concept is discussed in its respective chapter.

4.4.3 Hydrodynamic modeling limitations in the tool prevented assessment of the Intermediate Transfer Station.

## 4.5 Management System

4.5.1 A robust Management System is an essential element to ensure the efficient and effective management, control and flow of materiel through a seabase. This aspect of logistics should not be underestimated as the demands are significant for example;

- Multiple users on different platforms occurring simultaneously

- Need to establish source of item and the most efficient way to obtain it - the nearest platform with the item may not be the ‘best’ one given its particular operational stance etc.

- Security and system access

- Back-up capabilities

4.5.2 Chapter 14 discusses the Management System in more detail.

# 5 Functional Analysis

## 5.1 Approaches

5.1.1 The team identified the naval architectural issues and factors that limit at sea transfer through formal and non-formal functional analysis.

5.1.2 Discussions, meetings and interviews were held with academia, industry and a wide range of internal and external experts. In addition, the team used the Internet, viewed full scale and model test video footage and reviewed related reports and studies. A number of conferences were attended and visits to commercial facilities to view relevant systems were undertaken.

## 5.2 'Factory to Fort/Foxhole' Logistics

5.2.1 A functional analysis was required to provide a definition of the system, (i.e. the logistics chain) and to eliminate gaps in our understanding of the problem.

5.2.2 To initiate the concept development phase a number of assumptions had to be made with respect to the boundary within which the team should focus their efforts. Figure 2. illustrates the factory/fort to foxhole concept which is the complete logistics chain. The oval surrounding the seabase indicates the boundary within which the team focused its efforts.

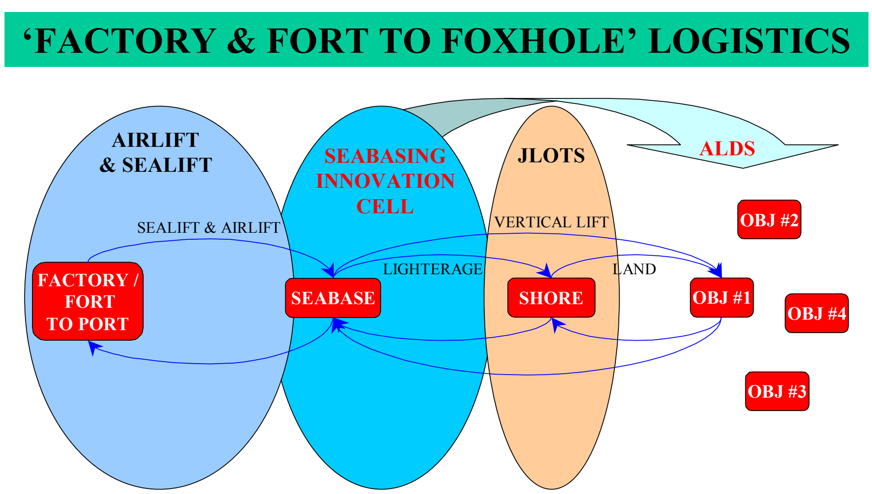



Figure 2. Seabasing within the Logistics Chain

The seabase was considered to have a 'supply' side that would interface with large ships such as the LMSR, containerships, etc. and a 'demand' side that would interface with aircraft and lighterage from the

JLOTS environment to support the forces ashore. This was driven by the teams understanding of concepts such as STOM, OMFTS, visibility of the US Marine Corps Seabasing Concept of Operations and the MPF(F) ship designs.

5.2.3 A diagram in Annex S highlights some of the logistics problems confronting the future seabase, particularly one that is required to remain over the horizon. Sustainment of forces ashore will dictate faster and 'heavier' delivery/extraction platforms.

5.2.4 Concepts such as STOM and OMFTS represent a different approach to war-fighting by attempting to minimize the footprint or Iron Mountain ashore by sending the 'teeth' ashore and keeping the 'tail' afloat. The ability to conduct at-sea transfer operations in higher seastates will ensure the continued sustainment of forces ashore such as a MEB sized force structure.

5.2.5 An unfriendly coastline could dictate that a seabase has to locate up to 200 nautical miles offshore. This assumption lead the team to focus on deep water solutions for transfer of goods as opposed to the shallow water operations conducted by JLOTS.

5.2.6 As the shoreline becomes more benign, the seabase (or parts of it) may have to move closer to shore to minimize transit distances and future re-supply sorties. Additionally, where it is still more practical, an iron mountain may be built ashore. The reality for some time to come is likely to be a mix of the two - iron mountain and seabasing.

## 5.3 Five Phases of Seabasing

5.3.1 The team identified five main phases to Seabasing as follows;

1. **At-sea Arrival & Assembly**…….of the seabase
2. **Initial Delivery & Selective Offload**…..…of forces ashore
3. **Indefinite Sustainment**…….of the forces ashore
4. **Reconstitution**…….of people and materiel
5. **Maintenance & Sustainment**…..…of other seabased platforms

5.3.2 The team did not consider the first and last phases in this study. The assumption was that the seabase had arrived and that the maintenance and sustainment are required even if the seabase is not there. So the concepts developed focused more on the initial delivery and selective offload, indefinite sustainment and reconstitution.

5.3.3 While it is relatively straight forward to speak to experts about current at-sea transfer problems, it is somewhat more difficult to pin down the latest generic thinking that would likely support infrastructure and materiel demands of a Seabase in the 2020 timeframe. Hence, a number of assumptions had to be made to allow the team to progress.

5.3.4 Having gained a reasonably sound and comprehensive understanding of the current and aspired at-sea transfer issues, cargo types, volumes and throughputs. Figure 2 in Annex I was produced to depict graphically the fundamental ‘steps’ in the logistics chain as it relates to seabasing.

5.3.5 The descriptive definition of the system enables modeling of the ‘flow’ through that system. It was the intention to use Extend (an industry standard discrete event modeler), however resource constraints prevented system-wide modeling. However, simple Excel models were developed to assess flow parameters for parts of the system to aid assessments such as selective offload alternatives. Various Automated Computer Aided Design (AutoCAD) arrangements that were developed to explore selective offload, Re-configurable spaces and stowage factor provided the basis for the Excel modeling. The Excel model is discussed in Section 10.11.

# 6 Concept Brainstorming

## 6.1 Groundwork

6.1.1 Prior to brainstorming for solutions, some effort was devoted to understanding the different cargo types and characteristics. Annex P presents a matrix showing the relationship between the cargo types and characteristics.

6.1.2 Following this, the team identified a range of supply platforms (to the seabase) and delivery / extraction platforms (to & from the shore). Next, numerous transfer methods currently employed today were identified and two cargo transfer scenarios were developed namely a static scenario and an underway scenario. The team then approximated the percentage of time a particular transfer mechanism would be used by that particular platform in both the static and delivery/extraction scenarios. Summing these percentages allowed percentage utilization factors to be determined and also the relative importance of each transfer mechanism to be identified.

6.1.3 Regarding the static scenario, it is of interest that the crane was the overall winner, followed by ramps and aircraft (loaded internally only) in second and third place, respectively.

6.1.4 For the underway scenario, the crane was the overall winner again, followed by ramps and aircraft (loaded internally only) in second and third place respectively. The results are similar to the static case. This work underlined the importance of cranes to a seabase and did influence the teams down-selection process in identifying concepts to develop and assess.

6.1.5 Static and underway matrices are included at Annexes Q and R respectively.

## 6.2 Matrix of Ideas & Grouping

6.2.1 Fifty plus concepts (Annex O) were identified through brainstorming. Grouping (Annex O also) allowed some high level study to occur to aid the down-selection of three preferred concepts for development and assessment and subsequent identification of the technology shortfalls.

6.2.2 During a progress meeting with the sponsor, Rear Admiral Cohen requested that the team give some consideration to concept(s) that looked towards the 2020 timeframe and encouraged the team to think more innovatively. Given limited resources, the team have included a concept known as the ALDS which was developed by a previous innovation cell.

6.2.3 ALDS bypasses the JLOTS environment by projecting gliders from a ship over the littorals to an altitude from which they glide to their target destination with their cargo. The team developed a simple cost model to compare the costs (personnel and fuel) of delivering a full load of supplies via a LCU to troops 30 miles inland by ALDS, truck and helicopter.

6.2.4 ALDS expanded the total number of concepts being developed to four.

6.2.5 Seabase enabling technologies such as re-configurable spaces and selective offload are significant areas that were studied because they were considered fundamental to the design and development of the concepts chosen.

## 6.3 Down-selection

6.3.1 Down-selection from the 50 plus concepts was performed by a voting system, following some initial research by team members into each ‘concept grouping’.

6.3.2 The concepts that received the highest number of votes were;

- Intermediate Transfer Station
- Deep Water Stable Craneship
- Seabase Hub

6.3.3 Each of the concepts is discussed in chapters 7, 8 and 9 respectively.

6.3.4 During a progress review meeting with Rear Admiral Cohen, he expressed some concern that our three concepts were too near-term and requested that we consider the 2020 timeframe. With a lack of resources the team ‘borrowed’ a concept that ‘fitted the bill’ from a previous innovation cell at Carderock. That concept was called Advanced Logistics Delivery System (ALDS)and was a late addition to our work.

6.3.5 It should be noted that there were a number of significant other concepts proposed that the team would have enjoyed exploring but chose not to. For example, the proposed lighter active motion compensation system was judged to have great potential for improving flow of materiel into lighters. The concept is basically a couple of remotely/automated piloted thrusters that would attach themselves (magnetically or via a vacuum) to the sides of a lighter waiting to load/offload at sea. The attached thrusters would then sense and counteract lighter motions while transfer is accomplished. This concept was deemed by the group to be in the JLOTS arena and hence was given a lower priority in favor of more seabased related concepts. However, the results of the seakeeping work has shown that the lighter motions are significant. The lighter does a lot of the ‘leg-work’ in the seabase environment, yet if its motions are such that they degrade the ability to load or unload safely then sustainment stops!

# 7 Intermediate Transfer Station (ITS)

## 7.1 Concept and Modes of Operation

7.1.1 The Intermediate Transfer Station (ITS) intends to use a Heavy Lift (HLS) or Float-on/Float-off (Flo/Flo) Ship partially ballasted in a med-moored configuration with large Roll-on/Roll-off (Ro/Ro) vessels to load and unload wheeled and tracked vehicles which are then driven onto lighters such as Landing Craft Air Cushion (LCACs), Landing Craft Utility (LCUs) and Landing Craft Mechanized (LCMs) for delivery to the shore.

7.1.2 A prime objective of the ITS is to greatly reduce current ramp cracking problems caused by torsional loading of the ramps resulting from relative angular motions between the ship and a platform. Bow thrusters on the med-moored delivery ships would be used to keep the delivery ship pointed into the prevailing seas. Consequently, pitch would dominate delivery ship motions. Motions of the ITS, aligned at right angles to the delivery ships, would be dominated by roll. Hence, the delivery ship pitches while the ITS rolls resulting in a ‘wrist-like’ movement with little or no torsion on the ramp hinge.

7.1.3 Figure 3 shows the ITS heeled over to create a high side to ‘ease’ stern ramp drop down and a low side (in the lee) to enable effective lighter interfacing. The LMSRs would be aligned head to the dominant sea direction. This ensures a much calmer seastate in the lee of ITS, providing better conditions for the lighter loading and offloading.

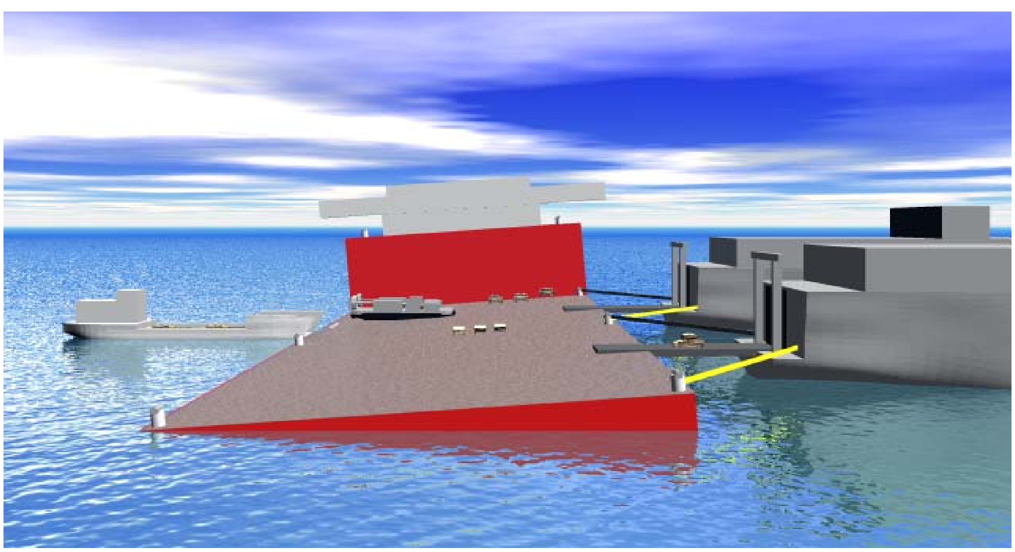


Figure 3. LMSRs med-moored to the ITS to load/offload Ro/Ro cargo

7.1.4 The ITS is well suited for a number of other roles in support of the seabase. During the initial stages of the seabase, the ITS could deliver limited range vessels such as lighters, causeways, barge sections and Mine Counter Measures Vessels (MCMV) into theatre. Once in theatre, the ITS ship can also provide a 'safe-haven' in rough weather or a dry docking facility for repairs / maintenance / inspection afloat should the seabase remain in theatre for extended periods. These applications can be accomplished with little modification of existing heavy lift ship concepts.

7.1.5 Addition of simple enhancements to the basic ITS concept expands the utility of the concept. For example, the ITS ship could also be used as a staging base for decontamination. A key enabling requirement for reconstitution is the ability for effective wash-down. Presently, wash-down is carried out ashore. In future, there will be a need to conduct wash-down afloat. It would seem that the ITS provides an almost ideal environment for wash-down capabilities prior to vehicles and equipment being reconstituted. A portable wash-down facility might be readily deployable in containerized form and assembled on the deck of the ITS. The ITS ship has sufficient tankage to hold large quantities of fresh water for wash-down and decontamination purposes.

7.1.6 The deck of the ITS provides a suitable at sea location for 'prepping' vehicles and cargo to go ashore in landing craft. The deck provides a buffer area where the vehicles can be fueled/de-fueled and explosives and munitions installed/removed. Presently vehicles are delivered to shore without munitions and explosives and with only 10% in their fuel tank. Once ashore, the fuel tanks are topped off and the vehicles are armed at the JLOTS facility. Seabasing requires this shore facility to be moved offshore and the ITS deck provides a suitable open air environment for this function. Similarly the ITS could serve as a re-fueling station for lighters.

7.1.7 The ITS ship inherently has a great deal of tanks. Use of some of this tankage volume for landing craft fuel and vehicle craft fuels is not a major issue. Also the open deck (rather than inboard) provides for safety in fueling vehicles and craft as well as storing and handling munitions/explosives. Relatively simple enhancements to enable safe handling and stowage of fuels and munitions would greatly enhance the utility of the ITS.

7.1.8 Figure 4 shows a rendered image of the concept proposed here;

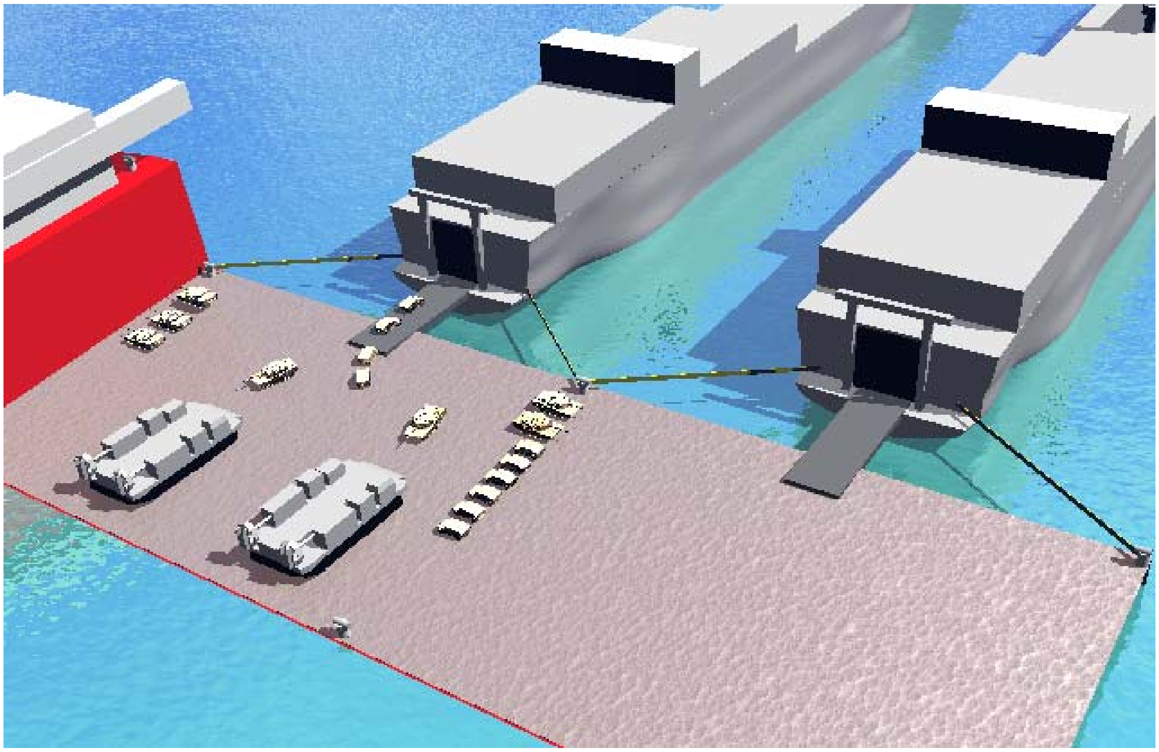


Figure 4 LMSRs med-moored with ITS to load LCACs

## 7.2 HLS Database

7.2.1 A database of existing Heavy Lift ships was compiled and a tabular summary (with color 'thumbnails') of existing Heavy Lift / Float-on / Float-Off ships is included in Annex F.

## 7.3 Med-Mooring Arrangements

7.3.1 The ITS will position it self across the wind and maintain that position using its fwd/aft thrusters. The ITS will then ballast down to its desired freeboard for the planned operation. To provide a beach for landing craft, port and starboard tanks can allow a 'list' to be 'applied' to the vessel quite easily. This list reduces the 'drop-height' for the stern ramps of Ro/Ro ships and should provide a 'beach' on the opposite side to enable efficient interfacing with lighters. For the enlarged Blue Marlin which has a 200 foot beam, this would result in a 4 degree list for a total difference in freeboard (port to starboard) of 14 feet. NOTE: As the seastate, wind, tide and 'operation' change the list should be altered accordingly or indeed removed.

7.3.2 The RO/RO ship would then back up towards the ITS amidships and bring two lines straight back and fasten to two temporary chocks installed on the ITS. These lines would have a mark (tape) identified on them for the length required. The Ro/Ro ship at this point can use its propellers and thrusters to maintain a constant perpendicular position from the ITS.

7.3.3 A line would then be passed from the Ro/Ro port and starboard to the ITS around temporary chocks and back to the ITS where they will be secured, these lines may be at approximately 45 degree angles to the ITS/Ro/Ro ships. The Ro/Ro ship stern ramp would then be lowered directly aft onto the ITS and the ramp verified that it sits in the proper location. Grease is placed on the deck where the ramp will land to reduce frictional forces.

7.3.4 The Ro/Ro ship would maintain a heading into the sea to minimize Ro/Ro ship roll. The ITS will remain perpendicular to the Ro/Ro ship using its propellers and/or thrusters if needed. The mooring lines should be kept taught by the Ro/Ro ship by either a slight forward speed or use of a smaller craft such as a tug pulling a line from the Ro/Ro ships bow.

7.3.5 Analysis of the dynamic forces between the two ships is needed to determine the number and sizing of lines between the ships. The sizing of the lines will generally be in accordance with the chock sizes on the Ro/Ro ship. Installing of temporary chocks on the ITS is not expected to be an issue since the deck is made with high margins to suite a variety of cargoes. If available, Global Positioning Systems (GPS) and other positioning systems could be used to assist in maintaining the position between the ships.

## 7.4 Military Specific ITS

7.4.1 A number of possible missions within a seabase exist that may benefit from the inclusion of an Intermediate Transfer Station; the use of modules on the ITS could potentially enhance the range of options and flexibility available to the joint force commander.

7.4.2 A large ‘working deck’ is essential. Beam is the most significant factor in terms of stability but needs to be balanced against powering, shipbuilding capacity, access (106’ max for Panama canal) etc. Such decks should have hard wearing non-skid coatings. Numerous deck fittings will be required, for tie-down points for containers, vehicles, fenders, mooring etc.

7.4.3 Integrated ballasting and dynamic positioning systems would enhance operability and station keeping. Ballast pumps should have high flow rates and redundancy. (Note: The Blue Marlin can ballast/de-ballast 3 feet in 20 minutes).

7.4.4 Active and passive roll stabilization systems should be investigated, although without the benefit of model testing it is at this stage unclear as to whether such systems would be needed.

7.4.5 Various discussions have indicated the need for any purpose built HLS to have its own cranage. The crane(s) could serve a number of missions and maintenance issues on the working deck as well as assisting with launch and retrieval of vehicles or moving any future deck modules on and off the deck. (Note the cranes do not have to be on the centerline; being offset may be a likely preference.)

7.4.6 Multiple deck operations will dictate the need for a central control center with good all-round visibility - such visibility might best be achieved by a central island structure that separates for example cargo loading/offloading from wash-down/decontamination. The ‘midships’ island structure could provide additional buoyancy for submerged operations and act as a housing for mooring bollards and winches etc. It would be useful to maintain fore and aft access ‘through’ or ‘around’ the central island structure.

7.4.7 A larger deck area has the added advantage of ‘enabling’ more tankage, some of that will be required for ballasting operations but not all. These other tanks would be available to be used for mission specific needs such as fuels-diesel/JP5/JP8, potable water, waste, decontamination fluids/gases, deicing fluids, Aqueous Film Forming Foam (AFFF) for fire fighting etc.

7.4.8 The deck also offers potential for storage of munitions and explosives possibly on deck in containers.

7.4.9 The deck of a HLS and its inherent seakeeping ability may offer the ability to load surface ship VLS tubes at sea; currently this evolution is limited to alongside in sheltered waters.

7.4.10 Of note, the United States SSN 688 class submarine is 362 feet long and 6,000 tons which is considerably less than the lifted DDG67 USS Cole 504 feet long and 8,300 tons.

7.4.11 An area of the deck or indeed the whole deck of the HLS could be used for helicopters operations. Note: Flight Deck length and width in feet LPH-602x104, LHA-820x118, LHD-819x106.

## 7.5 Stability

7.5.1 The stability and reserve of buoyancy are key concerns for these ships. In general, these vessels will operate either fully ballasted i.e. at maximum draught, or fully de-ballasted i.e. at minimum draught. They will also generally wait for a favorable weather window to ballast to their maximum draughts and stay in this condition for relatively short periods.

7.5.2 Here, the team are proposing to operate the ITS ship in the following way;

- In a partially ballasted condition i.e. with reduced freeboard
- Heeled over by ~3 degrees
- For potentially lengthy periods
- With a number of large and small vessels med-moored to it
- In higher seastates

7.5.3 Various HLS - Flo/Flo ship operators have been approached and none of these operational requirements have given them any particular cause for concern.

7.5.4 To determine the stability in a partially ballasted condition with a small angle of heel, it is necessary to have the following information;

- Linesplan / bodyplan / table of offsets / electronic model of hullform
- Tank condition for known drafts
- Corresponding vertical center of gravity (VCG)
- General Arrangement / deck plans
- Hydrostatics (very useful)

7.5.5 From this information, it is possible to determine the stability in this particular condition but also investigate how the stability (intact and damage) varies with draught. The variation in reserve of buoyancy with draught also needs to be determined.

7.5.6 The availability of such data (despite numerous requests) for a real ship was very difficult to get hold of. It is worthy of note that it would indeed be possible to design a Flo/Flo ship to be operated in this way that did have adequate stability.

7.5.7 Following attendance at the Offshore Technology Conference (OTC) in Houston, Texas 5-9 May 2003, an offshore HLS operator (Mr. Mark van Meel, President of NMA) did provide stability related information and a linesplan. Arriving very late in the project left little time to fully explore the stability characteristics of an existing ship operated in an ITS mode.

7.5.8 Having said this, the team did manage to produce a detailed electronic model of the ship including its internal ballast tank arrangement. This model was validated against the available hydrostatics and a very close correlation observed.

7.5.9 Given the lack of time, the priority was to understand more fully the stability of the vessel in the heeled condition. The International Maritime Organization (IMO) stability regulations were used (given the ship was designed to IMO regulations and is operated as a commercial ship), to determine the upright and heeled GZ curves[1].

7.5.10 Med-mooring of large (and smaller vessels such as a High Speed Vessel (HSV)) is an unknown at present. There will be operational impacts to manage the multi-vessel station keeping and physical impacts on the ITS platform. Both are considered achievable.

7.5.11 The operation of a HLS involves procedures and techniques that are particular to this type of vessel. Information was sought from operators of HLS in order to highlight immediate concerns as to the feasibility of the concept with respect to these. As a means of augmenting this and providing a quantifiable means of assessing the performance of such a ship in the condition identified a basic stability analysis was carried out.

7.5.12 Having obtained suitable data a 3D CAD model of the ship to be created in order to carry out analysis. This defined the basic hull form, tank boundaries and contents. Figure 5 shows a ‘screenshot’ of the model generated in the deep condition.

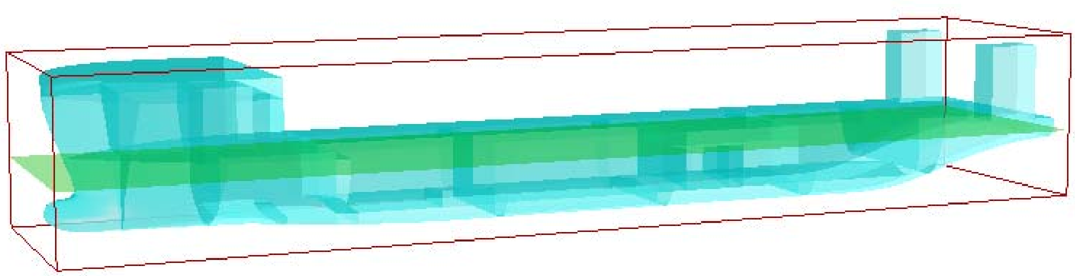


Figure 5 Heavy Lift Ship 3D model - surfaced deep displacement

[1] A GZ curve is a plot of righting lever against heel angle. Many stability characteristics can be obtained from the plot. The area under the curve is representative of the ability of a ship to return to the upright following an external disturbance such as wind and waves.

Figure 6 shows the same vessel in the submerged position;

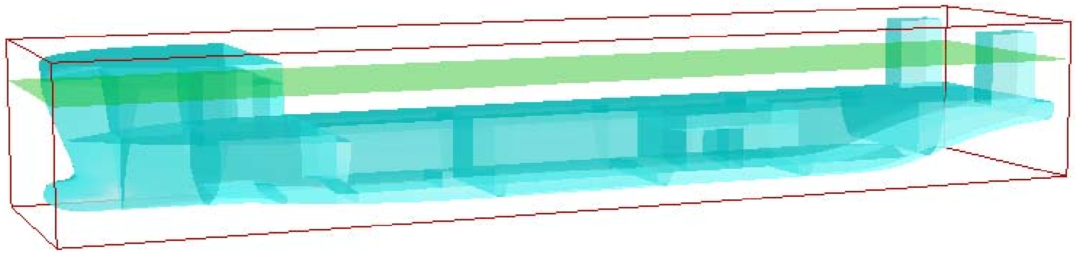


Figure 6 Heavy Lift Ship 3D model - submerged displacement

Once generated a number of conditions were analyzed

- Lightship : non-seagoing condition
- Deep Condition : typical seagoing condition
- Deep Submerged Condition
- Heeled Condition (i)
- Heeled Condition (ii)

7.5.13 The lightship condition was used primarily as a means of validating the model with stability data available. Once this was within acceptable limits the deep condition was defined and used as the basic condition for further ballasting to obtain submergence or heel as required.

7.5.14 The proposed mode of operation requires the vessel to be heeled over by several degrees. This is a function of the freeboard required on the windward side to allow ramp access to med-moored vessels and the level of deck inclination acceptable for safe operation of vehicles. In addition to this the submerged condition was analyzed to provide insight into the stability characteristics present.

7.5.15 The results obtained were compared with the relevant IMO Stability Criteria, in order to quantify the results obtained. These show that the generation of heel within the limits proposed will not cause a contravention of these regulations although this requires specific ballasting arrangements to allow this to occur.

### 7.6 Stability Results

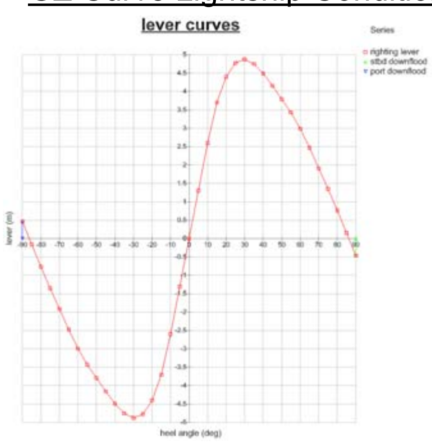
7.6.1 The results are not unexpected however they provide insight into the nature of Heavy Lift Ship operations and the constraints imposed by the requirement for good stability. Table 1 summarizes the results for the various conditions investigated;

| **Condition** | **Trim BP +ve by stern (m)** | **Mean Draught (m)** | **Draught AP (m)** | **Draught FP (m)** | **Heel Angle (deg)** | **Disp't (te)** | **GMts (m)** | **GMls (m)** | **GMtf (m)** | **GMlf (m)** |
|---|---|---|---|---|---|---|---|---|---|---|
| Lightship | -2.7 | 3.2 | 1.9 | 4.6 | 0.0 | 9,122 | 14.9 | 408.8 | 14.9 | 408.8 |
| **Deep Seagoing** | 2.1 | 7.2 | 8.2 | 6.1 | **0.0** | 25,672 | 9.6 | 277.6 | **9.3** | 277.2 |
| **Heeled (i)** | 0.9 | 8.2 | 8.6 | 7.7 | **-5.6** | 29,842 | 9.2 | 246.0 | **8.9** | 245.6 |
| Heeled (ii) | 0.2 | 8.5 | 8.6 | 8.4 | -6.4 | 30,866 | 7.1 | 230.9 | 6.4 | 230.3 |
| Deep-Submerged | 1.3 | 16.1 | 16.8 | 15.5 | -0.5 | 41,989 | 1.2 | 30.0 | 1.1 | 29.9 |

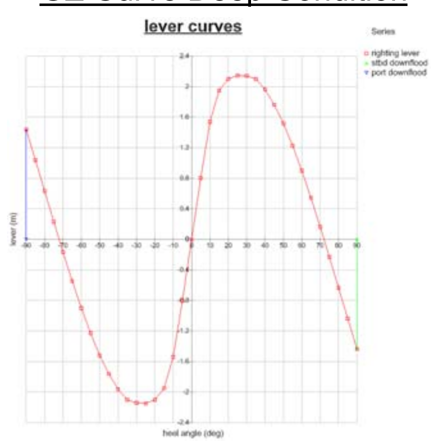
Table 1 Tabular summary of stability results

7.6.2 The associated GZ curves (i.e. plots of righting lever versus heel angle) are shown below;

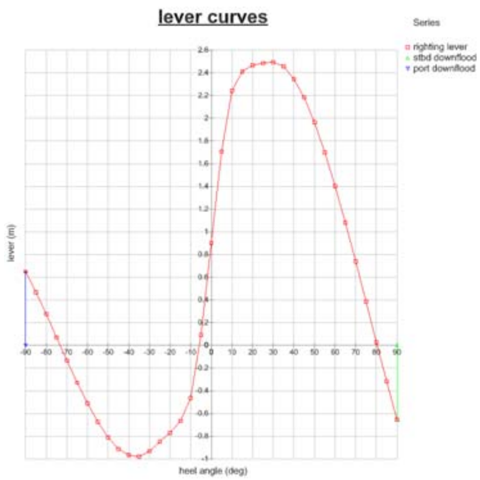
GZ Curve Lightship Condition



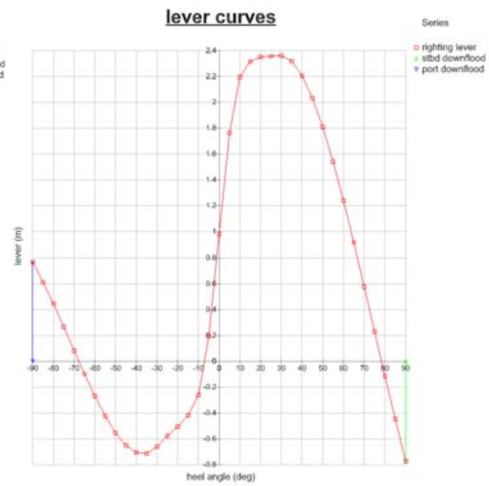

GZ Curve Deep Condition



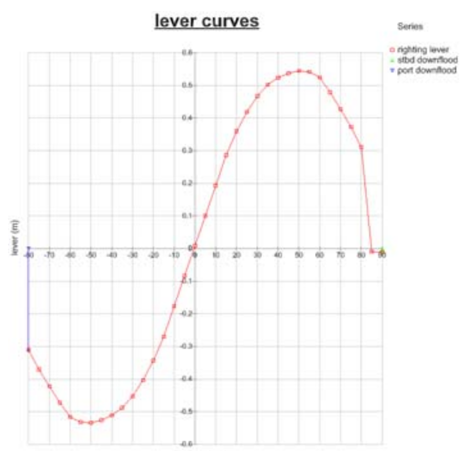
GZ Curve Heeled Condition (i)




GZ Curve Heeled Condition (ii)




GZ Curve Submerged Condition




## 7.7 Conclusions

7.7.1 In order to achieve the heeled condition defined above it has been necessary to partially fill certain ballast tanks. The free surfaces within such tanks can have a detrimental effect on stability. If used in a heeled condition on a regular basis the tankage is likely to require modification to allow this condition to be achieved without partial filling of tanks. However, the stability assessment undertaken here has taken accounted of the free surface effects in all partially filled tanks.

7.7.2 The trends in stability identified by this analysis are encouraging in that the heeled condition allows for control of the water-plane area such that a rapid, step change in area is avoided. This emulates the standard practice of trimming the vessel as it passes through the transitional zone where the deck submerges.

7.7.3 As stated earlier this has been a basic analysis that only covers one area of the use of an HLS for the purpose identified.

## 7.8 Seakeeping

7.8.1 While, seakeeping is an important aspect to this concept, the priority for the team was to understand the seakeeping of the deep water stable craneship and the seabase hub given the limited resources available.

7.8.2 In addition, the team were advised that the potential for some water on the deck of the ITS (as the ship rolls) would preclude modeling the ITS analytically as the current seakeeping tools could not model this particular scenario. Physical model testing may be more appropriate for the ITS. Although it is intended that the LMSRs or Ro/Ro ships would be aligned head to the dominant sea direction, thereby providing a protective lee on the ‘low’ side of the ITS, there are some concerns about waves washing onto the deck of the ITS. Tank testing rather than mathematical models would provide some valuable insight for varying seastates and direction.

## 7.9 Issues

7.9.1 One issue with HLS-Flo/Flo ships is loss of on-deck cargo during ballasting operations. The ITS becomes more stable as the deck is lowered to the water. Having the ITS partially awash on one side is new and unknown and requires further modeling and testing. If results are undesirable ramps may be used on the beach side of the HLS to reduce or eliminate the wash.

7.9.2 An other alternative during severe weather might be to use the stern of the ITS as the beach. This results in less beach frontage but is a possible alternate should sever weather require it. Some ITS ships have the stern open and do not have a stern deck house and so provide more flexibility in operations.

7.9.3 It is useful to note, particularly when bad weather gives little warning that most ITS can ballast up/down at a fairly rapid speed to on/off load all or an end of the ship (in the case of the MV Blue Marlin it is 2 inches per minute when the deck is above water and 8 inches per minute when below).

## 7.10 Military Benefit

7.10.1 The military benefit of an Intermediate Transfer Station is considered to be high. These include;

- Initial delivery and pre-positioning of limited range vessels such as landing craft, barges, powered causeways, MCMVs, craneships etc.
- Simultaneous load/offload to multiple lighters
- Lighter refuge in heavy weather or non-use
- Elimination of torsional loading of ramps
- Fast and efficient at-sea transfer of wheeled and tracked vehicles in SS3+
- Ability to move or respond to changes in objective - flexible and adaptable support to the seabase
- Open air refueling and re-arming
- Wash-down / decontamination facility

7.10.2 The options increase if a military specific ITS is designed and procured.

## 7.11 Recommendations

7.11.1 Seakeeping - current seakeeping tools can not cope with modeling the water surface when the HLS is heeled over. A simple physical model could be built to allow investigation of the ship response and deck wetness in different seastates and headings to determine the limiting seastates and headings and range of operability and to validate other hopes such as ramp torsion.

7.11.2 Stability - undertake a fuller intact (and possibly damage) stability analysis.

7.11.3 Structural Configuration - the implications of med-mooring on structural configuration would require investigation.

# 8 Deep water stable craneship

## 8.1 Concept and Modes of Operation

8.1.1 The Deep Water Stable Craneship consists of a catamaran upper hull with a detachable spar. Through careful ballasting the spar will rotate from its horizontal position through 90 degrees until it is vertically below the upper hull. Careful de-ballasting of the spar then provides sufficient buoyancy to raise the upper hull clear of the water surface.

8.1.2 The reason for doing this is to present a small water-plane area to passing wave systems. A small water-plane area is a key characteristic of good seakeeping.

8.1.3 The inspiration for this concept is Flipship.

Figures 7 & 8 - Flipship Photo Captions

8.1.4 This technology is not new. Flipship was launched in June 1962 and is still being operated today by the Scripps Institution of Oceanography in

San Diego, California. Flipship is owned by the Office of Naval Research (ONR).

8.1.5 By 1985, Flipship had completed more than 1000 days at sea with over 200 horizontal-vertical transitions.

8.1.6 Flipship has a horizontal displacement of 700 LT (Long Tons) and a vertical displacement of 2,104 LT. At 355 feet (108m) in length the draught in spar mode is 300 feet (91m). The diameter of the spar is 20 feet (6m) reduced to 12.5 feet (3.8m) at the top.

8.1.7 Flipship cost $7M at 1989 prices.

8.1.8 The concept here has a detachable spar. This is new and not a feature of Flipship. Being detachable, the utility of the platform is increased when operating in harbors, ports or in shallow water.

8.1.9 Flipship also needs to be towed to station, while this concept is self propelled. Thrusters are included on the spar to enable dynamic positioning and slow movement within the seabase while in spar mode.

## 8.2 Sizing Methodology

8.2.1 Having arrived at the concept of a deepwater stable craneship it was felt necessary to develop the idea in order to gain a more in depth understanding of the proposal. This took the form of a numerical sizing, to determine the geometrical form of the vessel and a stability analysis to determine the performance of the vessel when lifting the proposed loads.

8.2.2 In order to meet the time constraints of the project and achieve an appropriate level of detail the following approach was taken;

- Selection of appropriate load - one fully laden container
- Selection of suitable crane, fulfilling requirements for load and reach. (This is primarily used to asses the likely weight of such a system to input into subsequent tasks)
- Selection of a suitable SWATH or Catamaran for modification to crane ship
- Development of a Numerical Sizing spreadsheet calculation to determine the geometry and weight characteristics of the SPAR
- Initial assessment of Stability through the calculation of GM
- Development of 3D Solid Model in CAD package

- Detailed Assessment of Stability including the heel resulting from the load of one container at maximum crane extension.

8.2.3 Selection of suitable craneship - Rather than develop an entirely new design with the attending risk that this entails a previous design with the capacity to carry the selected crane system was chosen. This was the MV Duplus (later renamed MV Twin Drill), a SWATH research vessel built in 1969. The weight data for this was then suitably modified to take advances in materials into account. This is significant as the main driver behind the overall size of the SPAR is the top weight of the crane ship.

8.2.4 The screenshots in Figure 9, taken from 3D Solid Modeling software (Paramarine), illustrates the general arrangement of the Deepwater Stable Craneship in the deployed position (SPAR vertical) and the transit position (SPAR Horizontal). This is followed by a description of the processes undertaken in the development of this concept and the analysis supporting it.

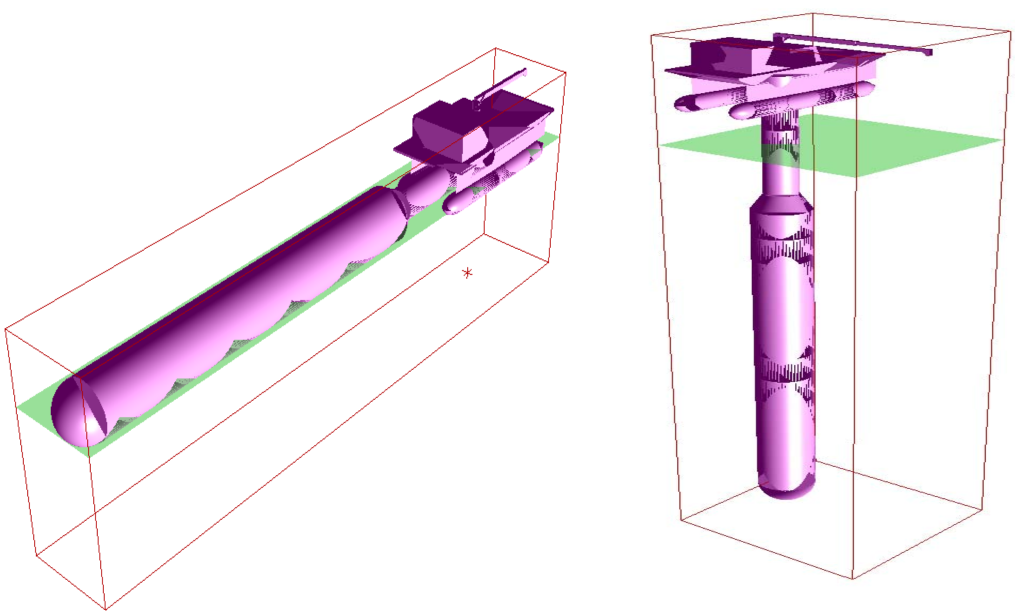


Figure 9 General configuration of the Deep Water Stable Craneship

8.2.5 Numerical sizing Spreadsheet - The following diagram illustrates the procedure of this calculation. The aim of which is to develop a ‘balanced design’ in terms of weight and buoyancy. This process identified drivers in the overall sizing of the SPAR which when combined with the structural constraints imposed helped to lead to a refinement of the SPAR geometry, to that illustrated.

8.2.6 Figure 10 shows the numerical sizing procedure adopted to determine the geometry and properties of the SPAR;

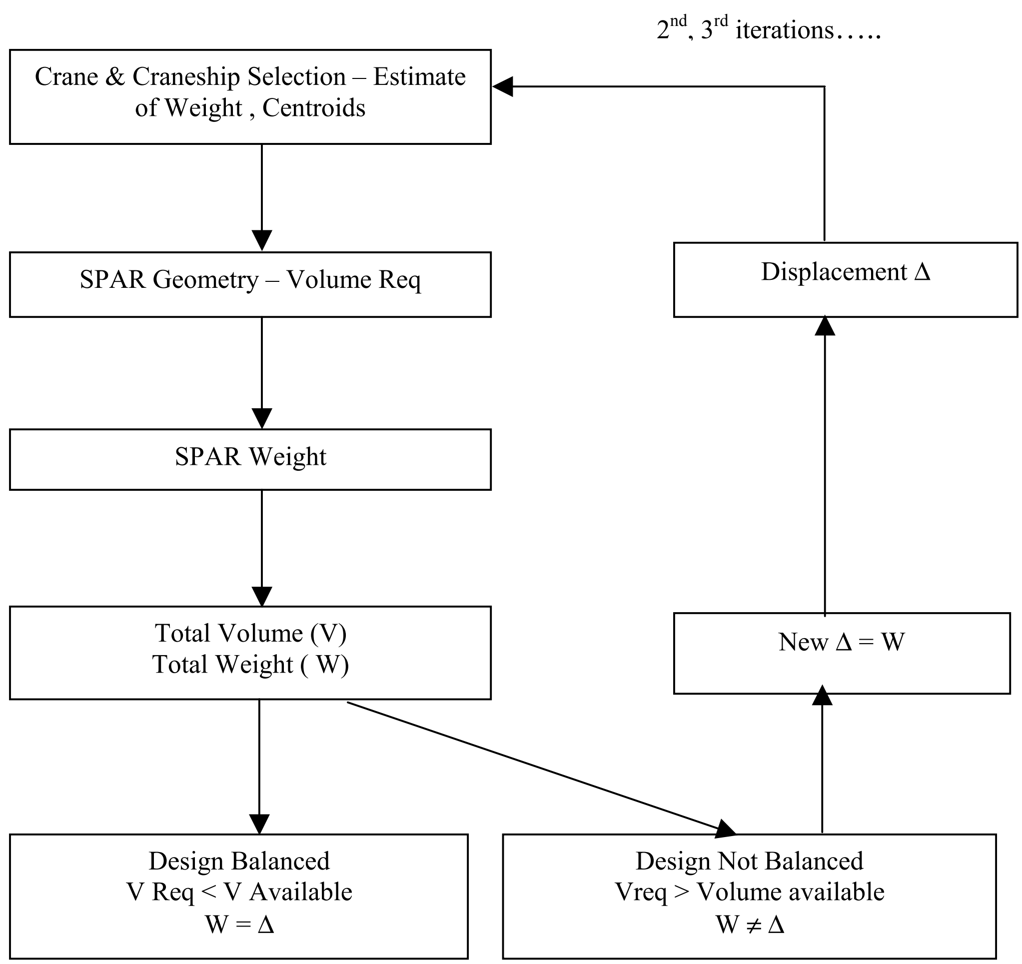



Figure 10. Spar numerical sizing procedure

8.2.7 Initial Stability Assessment through calculation of GM - In order to float at the desired draught the vessel must possess positive GM[2]. GM is a significant design driver in terms of the overall size of the spar. The magnitude of the GM is 'tuned' by the ballast capacity.

8.2.8 3D CAD Model - A model of the geometry output by the numerical sizing was created in a 3D Solid Model and Stability package Paramarine (Graphics Research Corporation Ltd, UK). This served to validate the numerical output of the spreadsheet and allowed quick assessment of the stability characteristics of the vessel.

8.2.9 Principle Characteristics -Table 2 summarizes the principle characteristics of the deep water stable craneship developed here;

| | | |
|---|---|---|
| **CATAMARAN** | | |
| Length Overall (m) | 46.9 | MV Duplus |
| Beam (m) | 17.1 | MV Duplus |
| Displacement (te) | 500.0 | Assumed Aluminum Construction |
| Wet Deck Clearance (m) | 2.7 | Assumed |
| **SPAR** | | |
| Depth (m) | 127.4 | |
| Clearance (m) | 16.0 | Water level to wet deck of catamaran |
| Diameter Upper Section (m) | 6.9 | 80% of distance between demi-hulls |
| Diameter Lower Section (m) | 11.9 | |
| Structural Weight (te) | 2,514 | |
| Ballast (te) | 8,000 | |
| **HYDROSTATICS** | | |
| GM (m) | 1.8 | In the upright condition |
| Total Displacement (te) | 11,047 | |
| Total Draught (m) | 111.4 | In the upright condition |

Table 2 Deep Water Stable Craneship Principle Characteristics

## 8.3 Stability during crane operations

8.3.1 A fully laden 20 foot container weighs approximately 30 tonnes. However, most containers are not loaded to this weight as it puts limitations on the number that can be stacked without crushing the bottom container. Here, a representative average weight of 15 tonnes was assumed.

8.3.2 The beam of a panamax ship is 106 (32.3m) or 53ft (16.2m) to the centerline. Factoring a suitable separation of say 5m between the container ship and the craneship and accounting for the half-beam of

[2] GM is the distance between the vertical center of gravity and the metacentre and is a measure of stability.

the craneship 28ft (8.5m) then the crane needs to be able to extend some 95ft (29m).

8.3.3 So the crane chosen was able to lift 15 tonnes at 30m. The crane selected was an existing Telescopic Boom Crane and weighs approximately 30 tonnes.

8.3.4 Once a model of the craneship had been produced, the same tool (Paramarine) was used to determine the heel of the vessel under such a lift. Paramarine estimated +/-1.5 degrees of heel with 15 tonnes at 30m with a GM of 1.8m.

## 8.4 Seakeeping

8.4.1 Based on the SPAR concept used by vessels such as Flipship the Deep Water Stable Craneship offers as its principal advantage the ability to operate in high seastates with low motions. Data obtained for Flipship revealed the following seakeeping characteristics;

- Maximum vertical oscillations have been measured on Flipship at less than 1/10 wave height in seas to 35 feet i.e. 3.5ft!
- Flipship has a heave period of 27 seconds and is designed to heave less than 18% of wave height in 17 second seas
- Flipship was also designed for 30 ft waves, but has survived 80ft swells with 22 second periods.

This data validates the spar ship concept at a scale of about 60% of the craneship and demonstrates the high degree of stability possible using spar ship technology.

8.4.2 In order to assess the performance of the Deep Water Stable Craneship and its interaction with other vessels ranging from the very large LMSR sized vessel to small vessels such as the LCU 2000 a seakeeping analysis was carried out. This took the form of a frequency domain analysis using panel method software WAMIT (Wave Analysis MIT). Six Degree of Freedom motions were calculated for the Deep Water Stable Craneship with a large vessel represented by an LMSR to port and a small vessel represented by an LCU2000 to starboard.

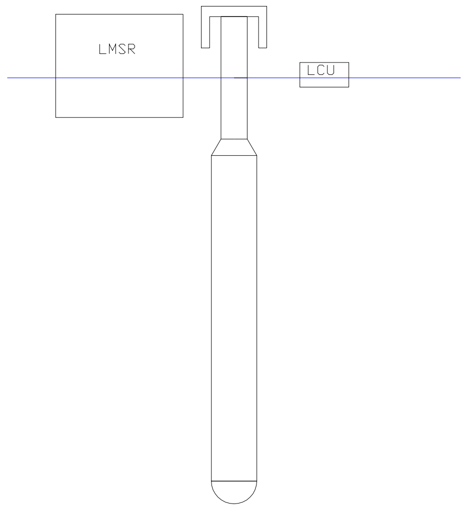



Figure 11 Relative position of concepts for seakeeping assessment

8.4.3 The following assumptions were made in this analysis;

- Bretsneider Sea Spectra (North Atlantic)
- Seastate (SS) SS4 ~1.8m wave heights, wave modal period 8.8 seconds
- SS2, SS3 & SS4 (plus SS5 & SS6)
- $360^0$ wave headings at $15^0$ intervals
- Varying wave modal period 8.8 through to 20 seconds

8.4.4 The intention behind the Deep Water Stable Craneship is to create a vessel that matches or surpasses the motion characteristics of a large monohull craneship.

8.4.5 Although the Deep Water Stable Craneship displaces only 17.3% of the LMSR displacement, it has significantly lower motions. For example, the heave motion of the spar is approximately 8% of that of the LMSR despite having only 17% of its displacement. This is shown in Table 3 below;

| SS4 Results | LMSR | SPAR | LCU2000 | SPAR / LMSR |
|---|---|---|---|---|
| RMS Heave (m) | 0.43 | 0.035 | 1.20 | **8.1%** |
| RMS Roll (deg) | 0.2 | 0.35 | 11.6 | 175% |
| Displacement (te) | 63,978 | 11,050 | 1,087 | **17.3%** |

Table 3 Seakeeping results (SS4) - comparison of roll & displacement

8.4.6 At first glance, it would appear that the Deep Water Stable Craneship has a much higher roll angle than the LMSR, and indeed it has. However, the magnitude of the roll angle needs to be tempered with the associated roll period. Table 4 summarizes the heave, roll and pitch periods for the various platforms in a Bretsneider (similar to North Atlantic) seastate 4.

| Platform | Heave | Roll | Pitch |
|---|---|---|---|
| LCU 2000 | 5.0 | 6.3 | 4.4 |
| LMSR | 8.4 | 20.4 | 8.2 |
| Deep Water Stable Craneship | 34.8 | 131.5 | 131.5 |
| Seabase Hub | 5.6 | 9.9 | 5.8 |
| Flipship | 27.0 | 42.0 | 42.0 |

Bretsneider Waves SS4, 1.8m waves, 8.8sec modal period

Table 4 Comparison of Natural Periods (seconds)

8.4.7 The Deep Water Stable Craneship has a roll angle of 0.35 degrees (75% greater than the LMSR) in SS4 however its roll period is some 132 seconds compared to 20 seconds for the LMSR. This large difference in roll period is very significant. Simply, a load hanging from a crane (such as that on an LMSR) will 'pendulate' i.e. oscillate. This pendulation is a function of the frequency of the exciting force, in this case the seastate. For the analysis here, the modal (i.e. most common) period for the seastate is much closer to the roll period of the LMSR than to the roll period of the Deep Water Stable Craneship. As the modal period of the waves approach the natural roll period of the LMSR, resonance begins to occur resulting in significant magnification of the motion and very noticeable pendulation. For the craneship, its roll period is so large and so remote from the modal period of the seastate that noticeable pendulation does not occur. This is a significant result for those trying to solve crane pendulation problems.

8.4.8 This conclusion is also borne out by Figure 12. Figure 12 shows a plot of magnification of pendulum motion that can result as the excitation period varies. The shape of this plot illustrates some of the physics behind the deep water stable craneship. Marine systems with a high roll period will tend towards a magnification factor of unity, and indeed when calculated this is where the craneship appears of the plot. Very short periods will has a high frequency and these are not generally applicable to marine vehicles. Where the natural period coincides with the period of exciting force then resonance results. This position is characterized by a tuning factor close to unity and is where the LCU2000 appears on the plot. While it appears that the LMSR performance is nearly as good as the Craneship and this is partly due to the size of the LMSR relative to the Craneship, it should be noted that it is extremely difficult to move towards the spar's position. Pendulation occurs readily on an LMSR but is much less apparent on the Deep Water Stable Craneship.

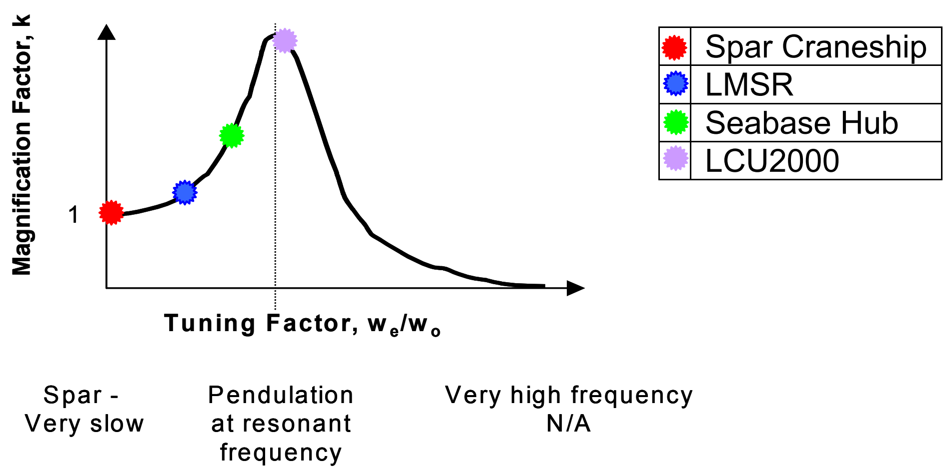



Figure 12 Graph of Magnification Factor versus Tuning Factor

8.4.9 It is also worth noting that the magnitudes of the roll motion here for the LMSR and the Craneship are very small at 0.2 degrees and 0.35 degrees respectively.

8.4.10 The following illustrations show the seakeeping results (presented as 360 degree polar plots) obtained for the LMSR, Deep Water Stable Craneship and LCU2000;

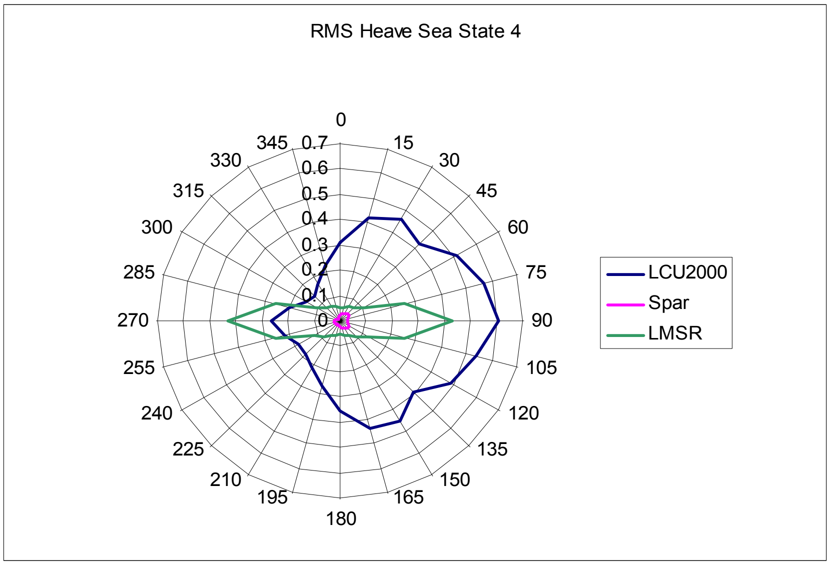



Figure 13 RMS Heave in Sea State 4

8.4.11 As can be seen the LMSR experiences the greatest heave motion in beam seas while the SPAR Craneship is largely unaffected, with very low heave motions. The LCU on the other hand is experiencing significant heave, particularly where shelter is not provided by the LMSR (i.e. $15^0$ to $165^0$).

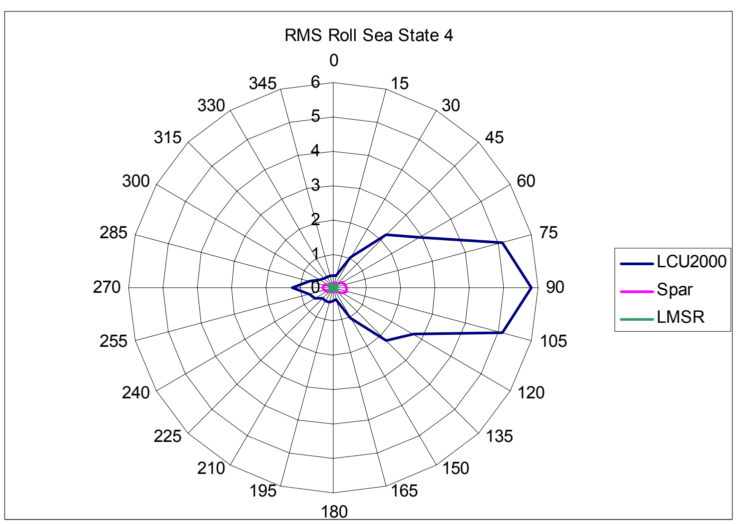



Figure 14 RMS Roll in Sea State 4

8.4.12 In roll the SPAR Craneship experiences very small motions. These are greater than the LMSR, although it should be noted that both very small. This is the first iteration of the conceptual design process for the spar craneship and it is proposed that the roll motion of the craneship could easily be reduced if required, however given its magnitude it is not considered necessary.

8.4.13 Figure 15 shows the polar plot results for RMS Pitch in Sea State 4.

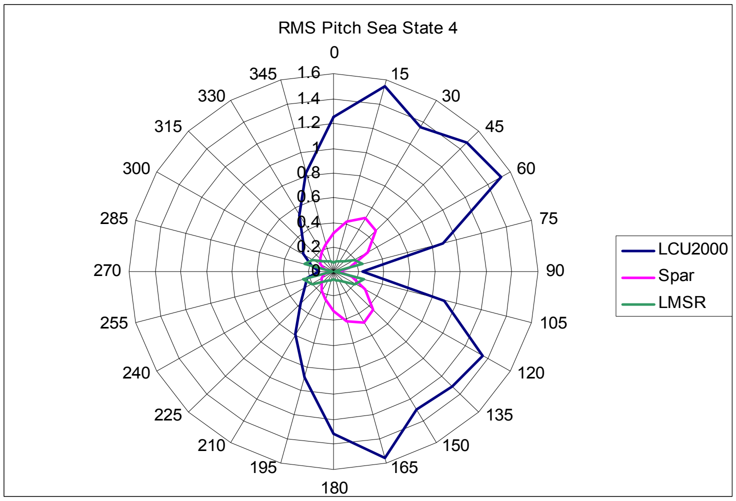



Figure 15 RMS Pitch in Sea State 4

8.4.14 In pitch both the LCU and Craneship can be seen to be experiencing sheltering effects (at certain headings) from the LMSR. Pitch for the SPAR is affected by sheltering, but remains low. The LMSR experiences little pitching as expected.

8.4.15 These results show that the SPAR Craneship configuration does allow for a very stable platform to be produced. For the conditions shown, the full benefit of the SPAR characteristics are not realized to the extent that they would be for higher seastates and higher modal periods. In these conditions the LMSR sized vessel will begin to see excitation while the SPAR remains relatively unaffected. It is in these conditions that the SPAR Craneship will offer significant benefit. It is realized however that this is only part of the problem in that the motion characteristics of smaller vessels servicing the Seabase remain large at higher seastates. This is perhaps an area for further investigation.

8.4.16 In addition to the low motions of the spar craneship, crane operations would also benefit from a reduction of pendulation due to the very long roll and pitch periods of the spar craneship. Since crane pendulum natural periods are very close to the roll periods of conventional ships (i.e. 10-20 seconds), the very long periods of the craneship (132 seconds) would result in much less pendulation.

## 8.5 Issues

8.5.1 Hinge/connector - The requirement for the SPAR to rotate from the horizontal transit position the vertical deployed position will require the use of a hinge mechanism. This is an area that is in need of further investigation although it is thought that this is not a critical problem at this stage.

8.5.2 Strakes - Current tethered SPAR systems utilize strakes which spiral around the outer diameter of the hull as a means of overcoming Vortex Induced Vibration (VIV). The flow of water past the SPAR causes lateral vibration which results in the rapid heeling from side to side of the SPAR. The use of strakes is an effective means of controlling this. The extent to which VIV will be a problem in a dynamically positioned SPAR is not known and is an area that requires investigation. The effect of Strakes on drag in transit will be a factor in their use and could limit their potential without significant design development

8.5.3 Thrusters - It is envisaged that the deepwater crane ship would be a free floating, dynamically positioned vessel. It is thought that thrusters placed at suitable locations within the SPAR will provide the ability for local in-area movement of the SPAR, for instance along the length of a stationary container ship. This is not seen as a major hurdle in terms of the technology of thrusters but the implementation in this hull form will require investigation.

8.5.4 Stability - As stated earlier the effect of GM on the overall size of the vessel is significant. It would be possible to produce a very stable SPAR with very small angles of heel when operating with cranes however these in all likelihood these spars would be very large. The use of a SPAR platform is seen as tackling the problems of crane pendulation by providing a very stable vessel to operate from. It is not seen as the only solution, as there will exist a trade off between the reduction in complexity of the crane anti-pendulation system and the size and complexity of the SPAR.

## 8.6 Military Benefit

8.6.1 It is envisaged that the deep water stable craneship would operate between the seabase hub or containerships and lighters on the ‘delivery’ side of the seabase. On the ‘supply’ side of the seabase, the craneship would operate between containerships/LMSRs etc. and the seabase hub to transfer containers, pallets, equipment, light vehicles etc.

8.6.2 Figure 16 shows the rendered image of the concept between a containership and a lighter.

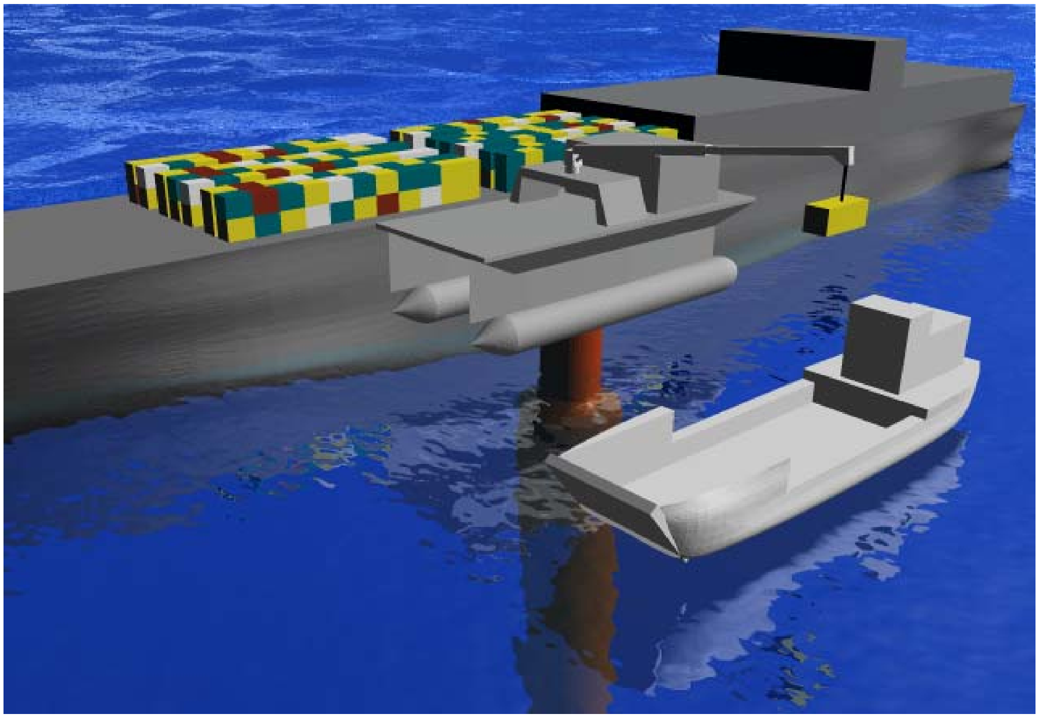


Figure 16 Deep water stable craneship between a containership & LCU

8.6.3 The military benefit comes from the ability of the craneship to keep working in higher seastates. Currently, crane operations above seastates 2 or 3 are generally abandoned because of pendulation of the load instigated by the roll motion of the host platform.

8.6.4 The Deep Water Stable Craneship provides the following significant military operational benefits;

- extends crane transfer of cargo
- provides a container transfer capability within the seabase
- reduces fleet wide cranage requirements
- increases interoperability with commercial vessels

8.6.5 It has been demonstrated here, albeit a the concept level, that the performance of a deep water stable craneship offers significant operational advantages in a seabased environment.

8.6.6 Primarily the removal of at-sea transfer of containers (for example) as the limiting factor in the ability of the joint task force commanders to maintain the operational tempo.

8.6.7 It is acknowledged that there are areas of high risk with this concept that have not yet been explored - namely the hinging mechanism. The worst case is that it is not possible to design a suitable hinge (which is hard to accept). Should a suitable hinging mechanism not be possible, this alone would not limit the possibility of a spar based craneship.

8.6.8 An alternative configuration of the spar could enable the spar and craneship to be deployed as a spar-causeway. Given the length of the spar (approximately 150m here) and the ability to drive the spar towards the beach and then ballast it in-situ and with a crane on the offshore end - the spar could be used as a causeway to assist in the loading and offloading of lighters.

8.6.9 The volume distribution is known - shaping of the spar should enable a causeway mode of operation as well as improving resistance for surface transit, while ensuring the excellent motions (determined from the seakeeping assessment) are unaffected. The seakeeping performance in spar mode does not depend on the shape of the water-plane just the area of the water-plane. This option is being developed further but is not reported here.

8.6.10 When on the surface, the inherent length (~150m here) of the spar may allow it to be used as a readily deployable and moveable breakwater. Coupling two or three spars together would provide an even greater degree of shielding / protection. This option is being developed further but is not reported here.

## 8.7 Recommendations

8.7.1 It is recommended that a more detailed point design is developed for this concept. Time has limited the extent to which the team could develop the concept here.

8.7.2 No work has been undertaken here with respect to the hinge and connector however it is hoped follow-on work will enable a fuller investigation of these aspects.

8.7.3 Fendering of the craneship is an issue. Locating it in the lee of the larger LMSR or container ship will inevitably result in the large vessels drifting onto the craneship, no matter how good the respective dynamic positioning systems are. The offshore industry have a lot of knowledge and practical experience of dynamic positioning in high seastates and this should be leveraged if at all possible.

8.7.4 There is scope to reduce the weight of craneship. Exploration of the use of aluminum and composites in the construction of the crane ship would allow significant reductions in the overall size of the SPAR.

8.7.5 A useful comparison could be made with respect to current ship based crane performance and the performance determined here for the deep water stable craneship.

8.7.6 Investigation into the resistance and powering of the craneship in both surfaced and spar-borne modes of operation.

8.7.7 The offshore industry report a 75% reduction in vertical motion on spars where strakes are fitted. The heave amplitudes calculated here do not warrant further reduction. Strakes would also increase the surfaced resistance and the ability to use the spar as a causeway. Our seakeeping performance indicates they would not be needed in our concept and mode of operation.

# 9 Seabase Hub

## 9.1 Why Seabase Hub?

9.1.1 One objective of Seabasing is to utilize the freedom of maneuver that the sea affords to respond quickly to changing objectives and to capitalize on the safety provided by over the horizon (OTH) positioning. To maximize this freedom, the existence of an 'iron-mountain' (i.e. materiel dump) ashore does not help. An iron mountain takes time to build up, has to be secured and that security has to be maintained. It is also extremely time consuming and labor intensive to move. This, coupled with the availability of willing host nation support, are some of the reasons why seabasing predicates the avoidance of an iron mountain ashore. However, the materiel must be provided from somewhere and so seabased platforms will provide a 'mobile home' for the materiel.

9.1.2 Here, the concept of a seabase hub was born out of a 'seabased iron-mountain' and the need to;

- reconstitute troops and materiel afloat
- provide indefinite sustainment to troops and equipment on the ground ashore
- enable the logistics supply/re-supply chain
- reduce the logistics burden on other seabased platforms
- facilitate efficient interoperability with commercial shipping

9.1.3 A dense packed arrangement of cargo will simply not work as it does not allow for the degree of selectivity desired. Instead, the ability to selectively chose materiel, muster and then package that materiel for the war-fighter will be particularly important to the operational tempo and sustainment of forces. Reconstitution and the breaking down of materiel will require space and this is unlikely to be provided by a dedicated area on a ship. Instead it is likely that such a space will have multiple uses and so the concept of re-configurable spaces and reconfiguration become important enablers to seabased platforms.

9.1.4 So, the seabase hub is viewed here as a concept to ease and enable the practicalities of providing a seabased 'iron-mountain.' Moreover, the utility of such a vessel is highlighted not only by the cargo stowage arrangements but by the cargo handling areas and the inherent ability to be highly selective, to reconstitute efficiently and to reconfigure readily to maximize the utility of the platform in the seabase.

9.1.5 From the outset, 100% selectivity was the design goal to highlight the ship impacts for such a high level of selectivity. Dense packing is already well understood and practiced within the military operational arena.

## 9.2 Concept and Modes of Operation

9.2.1 The seabase hub is a multi-hull (catamaran) ship concept to enable a number of seabased concepts to be explored. Primarily it is the utility of a floating warehouse with good seakeeping, designed with selective offload and reconstitution in mind from the outset. It explores the benefits of single tier arrangement of vehicles and pallets/containers in terms of stowage factor for 100% selective offload.

9.2.2 It is envisaged that the seabase hub would be capable of interfacing with both large and small platforms. Transfer of bulk and RO/RO cargoes are intrinsic aspects of the design.

9.2.3 The concept is also intended to allow study and improve understanding of multi-body interaction in seastates up to and including SS5.

9.2.4 Selective offload is a key feature. Commercially, automated car parking facilities exist (see Annex G) and are being used, air pallets are used to move large heavy loads with ease by Lockheed Martin and a simple hydraulic lift is used by car sales outlets to stow vehicles two high. These concepts are proven on land and the seabase hub is investigating employing similar concepts within the context of a seabase focusing on the initial delivery and then the sustainment of a Marine Expeditionary Brigade (MEB).

9.2.5 A dispenser concept (offering 100% selective offload) is proposed containing cells that are sized for humvees, containers and pallets. A total of 72 stacks are provided, split equally between the port and starboard sides. Each stack has five standardized cells that are located in each demi-hull and move vertically using linear induction motors to service the weather deck and the main cargo deck.

9.2.6 The impact of reconstitution is also addressed. A large dedicated space (170 feet x 48 feet) in the main cargo hold between the dispensers is provided for reconstitution.

9.2.7 Once the initial delivery and offload of vehicles has occurred there remains a large deck area that could be reconfigured to provide afloat maintenance and repair facilities, temporary berthing, recreational facilities (tennis courts, pools, etc.) and so the ship impacts of such temporary facilities has also been investigated.

9.2.8 The Re-configurable spaces work has attempted to identify the seabased functions best suited to reconfiguration.

9.2.9 All of these features are discussed in detail as follows;

- **Selective Offload** - Chapter 10
- **Dispenser** - Chapter 10, Section 10.8
- **Re-configurable Spaces** - Chapter 11
- **Seakeeping** - Chapter / Section - 7/7.8, 8/8.4, 9/9.5
- **Air Pallets** - Chapter 10, Section 10.4
- **Automated Parking Garages** - Annex G

## 9.3 Initial Sizing

9.3.1 To develop the concept of a seabase hub, an understanding of the cargo types and quantities was required. An option being investigated through the MPF(F) ship designs is to spread the materiel demands of a Marine Expeditionary Brigade (MEB) across six MPF(F) ships. Consequently, one sixth of a MEB was used as a starting point in sizing the seabase hub to add some reality to the concepts. A MEB consists of approximately 13,000 troops of which 6,800 would be put ashore.

9.3.2 Table 5 shows the breakdown of the materiel demands per day for the 6,800 troops;

| Materiel | ST/day |
|---|---|
| Water | 190 |
| Cargo Fuel | 225 |
| Dry Stores | |
| - Food | 15 |
| - Ammunition | 33 |
| - Other[3] | 27 |
| Sub-total (liquids) | 415 ST/day |
| Sub-total (dry stores) | 75 ST/day |
| TOTAL | 490 ST/day |

[3] Other - includes austere level of construction material, medical and parts re-supply at 7.8lb/man/day

Table 5. Materiel demands for MEB (6,800 troops) per day

9.3.3 A period of 30 days sustainment was deemed reasonable for a seabase hub particularly given the its function is mainly to provide the efficient sustainment and reconstitution following its initial delivery and offload.

9.3.4 It was assumed that the 75 short tonnes (ST) per day of dry cargo needs to be sustained for a 30 day period and is split equally between containers and pallets. This results in an all up weight 1125 ST in pallets and 1125 ST in containers. It was assumed that a standard pallet (4ftx4ftx4ft) weighs 0.675 ST and that a twenty foot ISO container (8ftx8ftx20ft) weighs 13 ST fully loaded. Hence, it was calculated that 1667 pallets and 87 containers are required to supply 6,800 troops with 75 ST/day of dry stores.

9.3.5 Vehicle listings for a MEB are numerous, vary in the vehicle types required and often conflict. An average was taken across the various MEB definitions and divided by six. The result being 357 vehicles. High Mobility Multi Wheeled Vehicles (HMMWVs - ‘humvees’) accounted for 170, Medium Tactical Vehicle Replacement (MTVR) trucks accounted for a further 80, Engineering Equipment Vehicles called for 42 leaving 10 other vehicle types to make up the remaining 65 vehicles.

9.3.6 So in short the seabase hub was sized around 100% selectivity of any of the following ;

- 1667 Pallets
- 87 Containers
- 170 HMMWVs
- 80 MTVRs

9.3.7 In addition, accommodation and hotel services are provided for the 1000 marines who remain afloat and consists of approximately one sixth of the additional 6,200 troops of the 13,000 troop MEB.

9.3.8 The seabase hub also carries its own gantry crane capable of servicing 420 feet along the length of the seabase hub and of commercial containerships. Providing the seabase hub with such a crane will mean that each of the six MPF(F) ships do not require such capability. In addition, the seabase hub will be able to interface with commercial containerships that generally do not carry their own crane relying instead on port facilities for loading and offloading on containers.

9.3.9 The capability of the seabase hub described above represents one sixth (16.7%) of the MEB in all but one area - vehicles. Only 250 of the 357 vehicles are carried which represents 11.7% instead of 16.7% - a 5% shortfall (~107 vehicles). These will need to be carried by the six MPF(F) ships. This represents an additional burden on them of 18 vehicles each, while the seabase hub removes the majority of the sustainability requirements/features from the MPF(F) ships. Of course the seabase hub does allow the option to dense pack in which the remaining 107 vehicles could be accommodated. Dense packing may be acceptable for 'like or similar' vehicles where the requirement to choose a specific vehicle is redundant.

9.3.10 The sustainability features included in the seabase hub are;

- Large 20ft TEU container capable gantry crane
- Dedicated space for reconstitution
- Large volume dedicated to stores
- Dispenser and Air Pallet concepts for 100% selectivity
- Good seakeeping hullform
- Accommodation & hotel facilities for 1000 troops

## 9.4 General Arrangement

9.4.1 In developing the Seabase Hub the main focus of effort has been on the design of the cargo spaces and the integration of this with the overall ship concept. Time constraints are such that it has not been possible to work up a detailed concept design. Instead a similar design developed for another project was modified through replacement of the cargo deck. Figure 17 shows the main cargo deck of the seabase hub.

9.4.2 Cargo Deck - The layout of the main cargo deck is driven by the requirements of the Selective Offload Dispenser System, Uptake and Down take Arrangements, Internal Access, Vehicle Storage and External Access.

9.4.3 Strength Deck - The main watertight bulkheads extend up to the deck-head in this area. This was one of the main drivers in having the cargo deck above the main strength deck as it was felt that these would have proved difficult to integrate with the movement of vehicles. The accommodation and hotel services for 1000 marines are provided on the strength deck.

9.4.4 Propulsion - It is envisaged that the prime movers will be located in the demi-hulls below the superstructure. Provision has been made for uptakes / downtakes in this area.

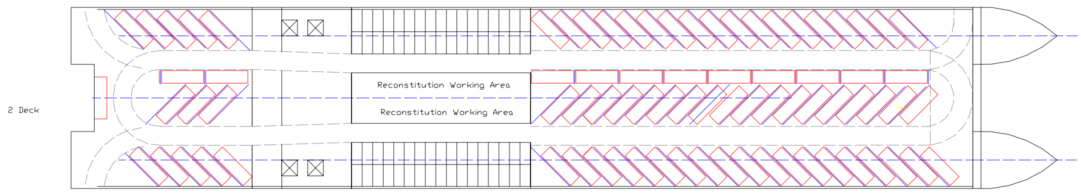



Figure 17 General arrangement of Seabase Hub main cargo deck

9.4.5 Design Balance - Although a General arrangement is given here it must be stressed that this is not a "Balanced Design" in the sense that a weight audit and assessment of area and volume requirements has not extended beyond the most basic level. It is proposed as an area of further work, that a concept such as this, be worked up as a point design. The aim here was to highlight the benefits of a large single cargo deck on a catamaran optimized for selective offload.

9.4.6 Figure 18 shows a 3D CAD model of the Seabase Hub created in Paramarine.

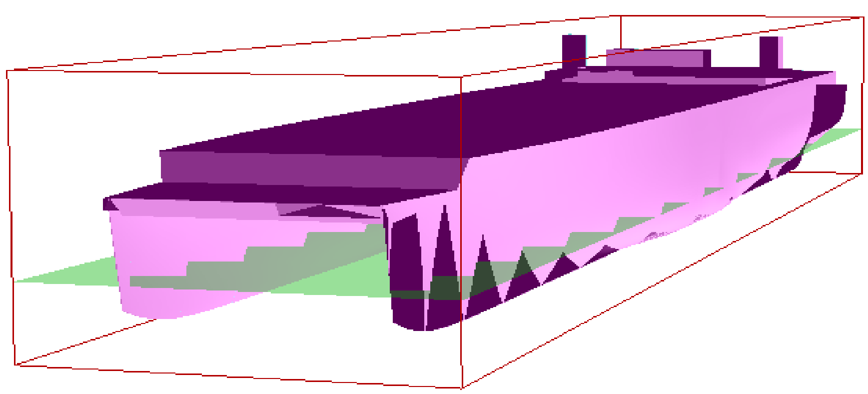


Figure 18 Seabase Hub 3D CAD model created in Paramarine

9.4.7 The internal cargo deck arrangement of the seabase hub is shown in Figure 19.

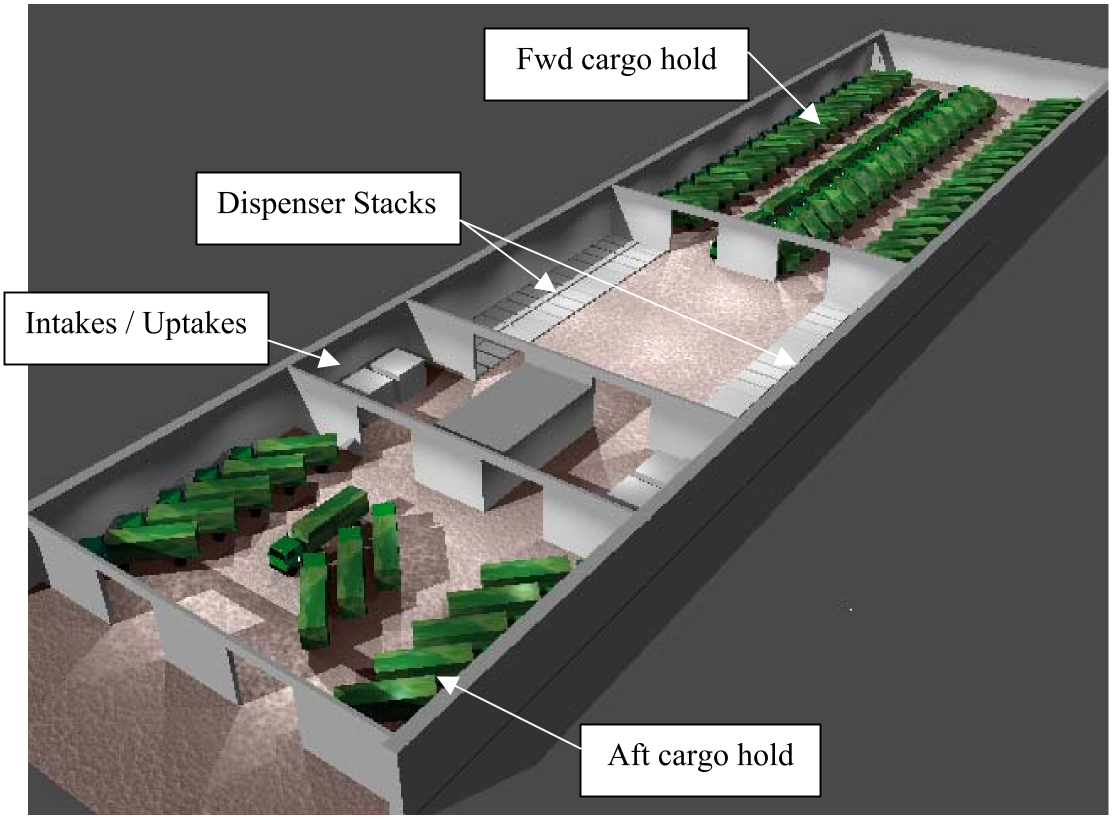



Figure 19 Cargo deck of Seabase Hub

9.4.8 Figure 20 also shows the rendered 3D solid model of the Seabase Hub concept - note the large container capable gantry crane that services a large proportion of the ships length (and commercial containerships).

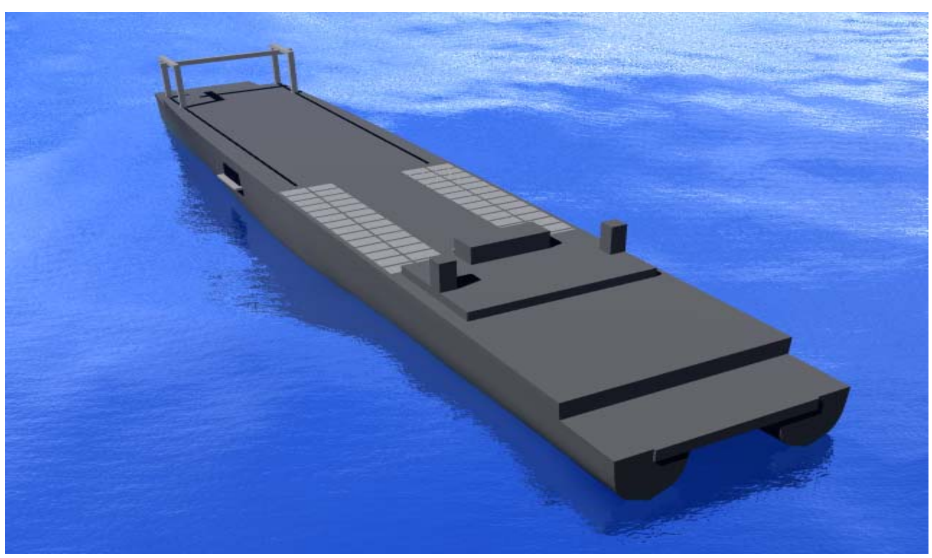


Figure 20 Seabase Hub - large catamaran

9.4.9 Table 6 tabulates the principle characteristics of the seabase hub;

| | Feet | Metres |
|---|---|---|
| Length oa | 936.9 | 285.6 |
| Length Cargo Deck Vehicles | 592.4 | 180.6 |
| Length - Dispenser System | 170.0 | 51.8 |
| Beam-oa | 172.0 | 52.4 |
| Beam-Cargo Deck | 168.0 | 51.2 |
| Draught | 30.0 | 9.1 |
| Depth | 70.0 | 21.3 |
| Deck Height | 10.0 | 3.0 |
| Cargo Deck Height | 20.0 | 6.1 |
| Displacement (Tons) | 34450 | 34450 |

Table 6 Seabase Hub principle characteristics

9.4.10 See Annex E for further details of the ship arrangement and layout.

## 9.5 Seakeeping

9.5.1 During the investigation of the transfer issues surrounding seabasing one concept proposed was a wet-well which would allow a small vessel to pass between the hulls of a large catamaran and transfer goods, vertically or by means of a ramp, to the large vessel.

9.5.2 The development of the Seabase Hub allowed the opportunity to analyze this problem in addition to single tier layout, selective offload and reconfiguration. Also the effect of a large vessel moored alongside the Hub was analyzed. This was necessary to assess the relative motions and the impact on the transfer of good using cranes.

9.5.3 The most effective way to conduct the analysis was to model a scenario with a large vessel moored alongside the Seabase Hub, as would be the case during the transfer of containers to the Hub, and with a LCU positioned between the hulls of the hub, representing the wet well situation described above.

9.5.4 Time constraints precluded the modeling of these situations separately, however the positioning of the large monohull (represented by a LMSR) was such that interference effects on the LCU positioned between the Seabase Hub demi-hulls was minimized.

9.5.5 The following drawing illustrates this;

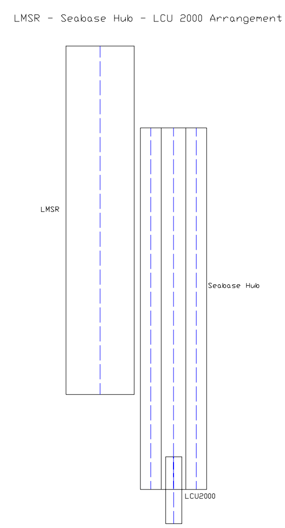



Figure 21 Plan view of relative positions of LMSR, Seabase Hub and LCU2000

9.5.6 Analysis was carried out in WAMIT, with motions calculated for all headings in Sea state 2 to Sea State 4 at zero speed. The latter constraint is a function of the software used and should not be seen as a restriction of the concept as underway transfer is an area that is applicable to this concept and is proposed as an area for further work.

9.5.7 The RMS Heave results (in seastate 4) are shown in figure 22;

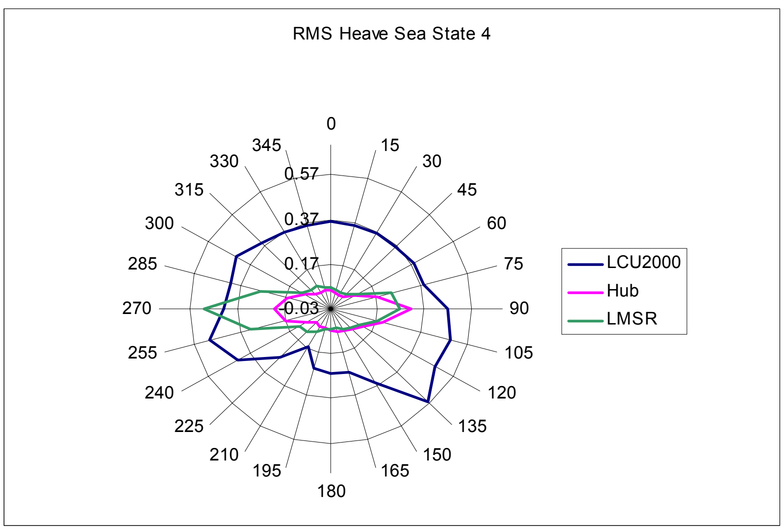



Figure 22 RMS Heave results in seastate 4

9.5.8 In Heave the LCU experiences large excitations in all headings as expected. This is due to the natural period of the vessel approaching that of the sea state. The Hub and LMSR experience low excitation in both head and following seas. As the sea approaches beam sea conditions larger motions are experienced by the Seabase Hub; this is principally due to resonance as a function of heading.

9.5.9 At modal periods of 8.8 seconds and 9.5 seconds the wavelengths are 120m and 126m respectively. The beam is approximately half this at 52.4m. In effect he Hub is following the contour of the sea.

9.5.10 The RMS Roll results (in seastate 4) are shown in figure 23;

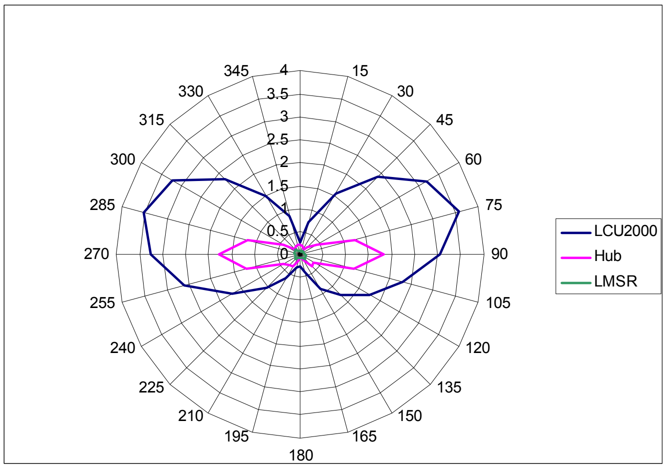



Figure 23 RMS Roll results in seastate 4

9.5.11 In roll all the vessels experience low excitation for both head and following seas. The LCU benefits from the sheltering effect of the Seabase Hub as expected. The LMSR experiences low roll excitation in all headings at this sea state. This is not replicated by the Seabase Hub however, which is rolling by a greater magnitude than the LMSR in seas directly on the beam.

9.5.12 This follows the trend in heave and is due to resonance as a function of heading, with the roll natural period approaching that of the sea spectra. In this case the roll transfer function peaks at 9.3 seconds, close to the wave modal periods of 8.8 seconds and 9.5 seconds.

9.5.13 In Pitch the LCU shows much greater motions than the Seabase Hub and LMSR as expected. Interference from the LMSR appears to be affecting the Pitch of the LCU where seas are approaching from the port bow.

9.5.14 The RMS Pitch results (in seastate 4) are shown in figure 24;

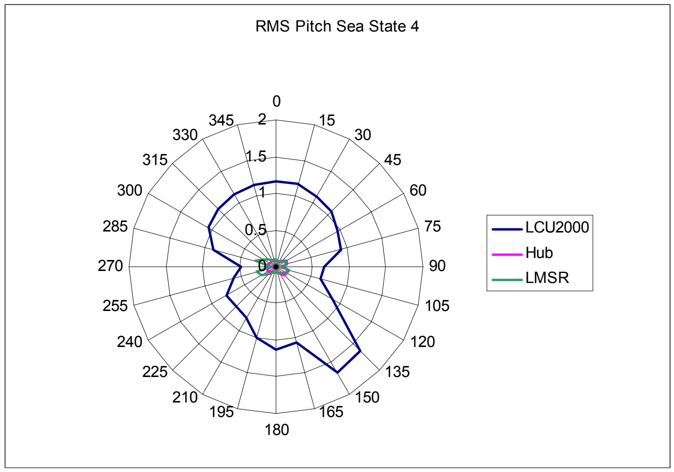



Figure 24 RMS Pitch results in seastate 4

9.5.15 The above motion phenomena have been attributed to the differences in natural period of the vessel in question, relative to the period of the sea spectra. Figure 25 augments this by showing the roll, pitch and heave periods of the LMSR, LCU and Craneship in addition to the Pierson-Moskowitz Spectra.

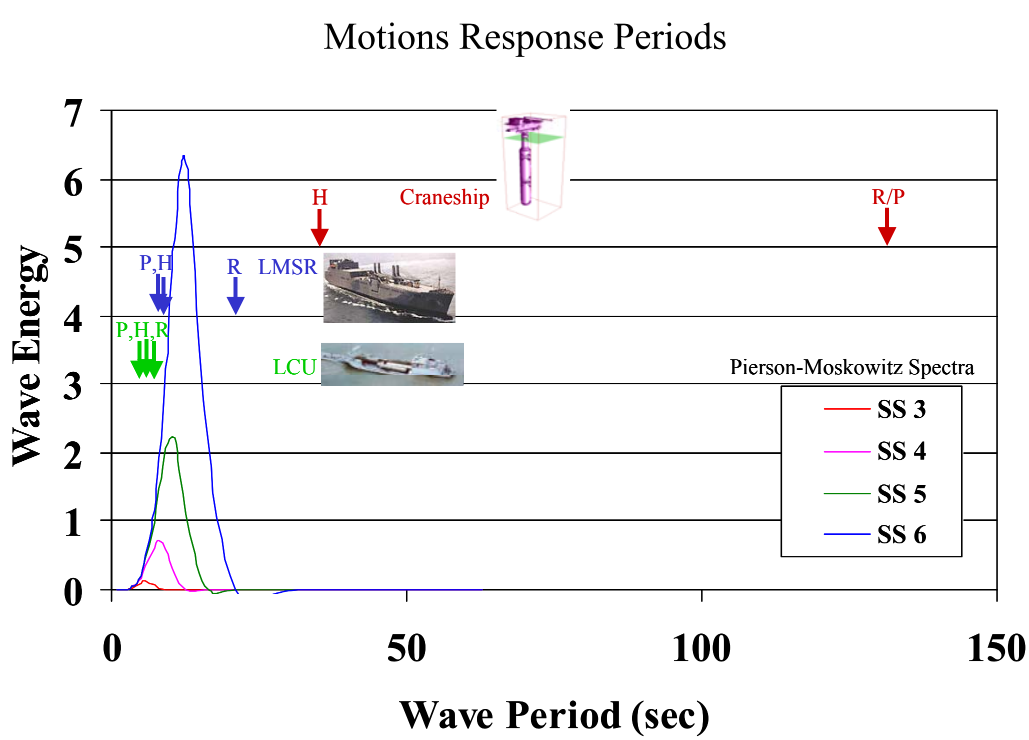


Figure 25 Roll (R), Pitch (P) and Heave (H) periods

9.5.16 In conclusion the LMSR and LCU behaved as expected in the conditions, however the Seabase Hub does show areas for concern although it is thought that these are drivers for tuning and refinement of the concept rather than critical problems.

9.5.17 The LCU was seen to benefit from the shelter of the Seabase Hub when operating between the hulls of the Seabase Hub, the motions of the LCU remain relatively large and indicate that a means of suppressing the motions of small craft may be an area for consideration as a means increasing the ability to transfer goods at sea.

## 9.6 Military Benefit

9.6.1 The Seabase Hub is envisaged to deliver and offload one sixth of a Marine Expeditionary Brigade (MEB). Following this initial delivery and offload phase the seabase hub will take on the ‘lions share’ of the indefinite sustainment and reconstitution of the total forces ashore (~6,800 troops and equipment).

9.6.2 The benefit to the military of such a platform, being designed with sustainment and reconstitution in mind from the start, is primarily avoidance of the fleet wide penalties of undertaking these tasks i.e. the seabase hub reduces the burden of requirements throughout the seabase.

9.6.3 Selective offload and in particular 100% selectivity demand space. Breaking up stores for mission packaging, reconstitution activities, afloat maintenance and repair etc all demand space. The seabase hub enables effective reconfiguration and reconstitution within the seabase.

9.6.4 The future Seabase will interface with many commercial vessels that do not carry their own cranes, as they rely heavily on port facilities. The Seabase Hub carries its own gantry crane capable of servicing 420ft of length of a panamax container ships without the need for either vessel moving. Providing such a capability even on ships like MPF(F) is likely to be very expensive.

9.6.5 Use of the catamaran hull form combined with automated systems such as the cargo dispenser result in a concept that requires only horizontal movement of cargo. Such a concept should result in significant improvement in cargo transfer rates and reductions in manpower requirements. While the anticipated benefits were not quantified through discrete event modeling of the seabase hub, such a study was done previously for a similar concept developed for the ADC(X) underway replenishment ship program. Transfer of cargo from hold to UNREP and VERTREP stations was analyzed using an Extend model for a large catamaran with cargo stowed on the UNREP deck as well as a conventional monohull with cargo stowed below-decks. The analysis showed cargo transfer rates were 40-60% higher for the catamaran. This performance advantage could be reduced somewhat by substantially increasing the numbers of personnel and cargo handling vehicles made available to the monohull. However, the advantage of horizontal stowage versus vertical stowage was clearly evident.

## 9.7 Recommendations

9.7.1 This is a concept. A detailed design has not been undertaken due primarily to time constraints. It is fair to acknowledge that reasonable effort has gone into sizing the ship and ensuring efficient ‘flow’ throughout the ship. Care has been taken to consider the impact of bulkhead positioning, intakes and uptakes for the main engines and balancing weight and buoyancy.

9.7.2 However, the weight estimates are estimates and hence in some areas represent high risk. The dispenser concept is yet to be ‘worked up’ and its system impacts determined.

9.7.3 The recommendation is to work up a more detailed design for this concept, to determine the;

- overall ship size and ‘optimum’ layout
- flow of materiel through the ship (perhaps a comparative study with LMSR or current MPF(F) designs)
- resistance & powering characteristics hence range & speed
- utility to the joint force commander

# 10 Selective Offload (100%)

## 10.1 Overview

10.1.1 Selective Onload/Offload or 100% Selectivity is the ability to stow or retrieve a specific cargo in/from any of the stowage 'cells' designated for that particular cargo, without having to move any other cargo in the process. Generally, 100% selectivity is accompanied by minimal reverse movement limited to arrangements such as in angled parking.

10.1.2 Various concepts were developed and explored for selective offload. In all cases the goal was 100% selectivity. The concepts include;

- **<u>Alternative deck layouts/arrangements</u>;**
  - **Angled ($45^0$) Parking**
    - Conventional Decks with;
      - Vertical Lifts/Elevators
      - Spiral Ramps (1 and 2 full spiral concepts)
    - Single Tier Layout
  - **Air Pallets (enabler for dense packing)**
    - Conventional Decks with;
      - Vertical Lifts/Elevators
      - Spiral Ramps (half, full and 2 full spiral concepts)
    - Single Tier Layout
- **<u>Dispenser Concept</u>**

10.1.3 Each of these concepts is discussed in detail in the remainder of this chapter.

## 10.2 Alternative Deck Layouts

10.2.1 A total of ten different arrangements were investigated. This study investigated two different stowage arrangements;

- constrained (existing ship arrangements similar to an LMSR)

- an unconstrained arrangement (i.e. single tier)

10.2.2 In investigating the unconstrained version, the design focus was to optimize the layout to accommodate the designated vehicles ensuring 100% selectivity of all vehicles stowed.

10.2.3 Table 7. summarizes the alternative arrangements investigated and shows their corresponding stowage factors;

| | Option | 'Palletised' | $45^0$ Parking |
|---|---|---|---|
| 1 | Single Tier | 47.0% | 40.2% |
| 2 | 3 x Decks + 4 Elevators (panama) | 26.7% | 27.3% |
| 3 | 3 x Decks + 4 Elevators (<106ft) | 31.3% | N/A |
| 4 | 3 x Decks + 2 x Half Spirals | 31.1% | 22.0% |
| 5 | 3 x Decks + 2 x Spirals | 26.8% | 19.6% |

Table 7. 100% Selective Offload Arrangements

10.2.4 It is important to note that with angled parking, only 2 elevators will fit per deck due to the turning area the vehicles require.

10.2.5 The designated vehicles were determined by using 1/6$^{th}$ of the 2015 Marine Expeditionary Brigade (MEB) requirements. Within this 1/6$^{th}$, approximately 80 large vehicles are close in size / footprint. See Annex T for a tabular summary of vehicles and their general characteristics. For this study, the largest footprint was taken to size the cargo holds. It was assumed that the vehicles would be sized 12ftx40ft: 12ft being the width of an M1A1 tank, and 40ft being the length of a Logistics Support Vehicle (LSV).

10.2.6 The single tier arrangement was designed for the 80 vehicles mentioned above. However, in order to divide the vehicles evenly over three decks for the 'conventional' arrangement, including the elevator/vertical lift and spiral deck layouts, 84 vehicles were used, with 28 vehicles on each deck.

10.2.7 All arrangements were constructed using a turning radius of an M818 and M871. Diagrams showing turning radius footprints for 45 to 45 degrees and 90 and 180 degree turns are in Annexes W and arrangements in Ref.[6]. This was assumed to be the closest vehicle to an LSV/M1A1 mix. There was difficulty in locating accurate turning radiuses for certain vehicles. Many of these 80 vehicles are not backed over long distances. Arrangements were laid out with this in mind. This requirement leads to additional deck space for access which decreases the stowage factor.

10.2.8 After the initial investigation it was decided that concepts should be designed using two different ship beams; a constrained beam (to accommodate panamax) and an unconstrained beam sized with reasonable length to breadth (L/B) considerations for resistance and structural strength and to enable adequate space for parking and access.

10.2.9 In the unconstrained beam layout, the maximum beam used was 172ft (52.4m) to achieve full optimization of the space. In the constrained version, a panama size ship was used. The reference to panama simply implies that particular arrangement was constrained to a Panama Canal beam or less i.e. 106ft (32.3m). In several situations however, less than a Panama Size ship was used to optimize the area and produce a better stowage factor. Since the vertical lifts/elevators and spiral ramps are used in a multi-deck cargo arrangement, only a Panamax size ship or smaller was assumed.

10.2.10 AutoCAD drawings were produced for each layout so that the associated Stowage Factors could be determined. For each of the arrangements, the stowage factor was calculated and these are graphed in Annex K. All of the AutoCAD drawings are in Annex V. Drawings showing the turning areas required by the vehicles are in Annex W.

## 10.3 Angled Parking

10.3.1 Angled parking studies were undertaken to determine the most beneficial arrangement. In researching the conventional parking lot design industry, several assumptions were found, see Ref.[2] and Annex K;

- The most popular angles for parking stalls are $60^{0}$, $45^{0}$, and $90^{0}$.
- The most common angle for parking is the $60^{0}$ angle because of the ease of operation it provides. This angle permits reasonable traffic lane widths and eases entry and exit of the parking stall.
- Where lot size restricts the dimensions available for aisles and stalls, a $45^{0}$ angle may be used. The smaller change of direction required to enter and back-out of the stall space permits use of narrower aisles. The $45^{0}$ angle reduces the total number of parking spaces for a given area but is the only acceptable angle for a herringbone parking lot pattern.

- The $90^0$ parking angle provides the most parking spaces for a given area. The high degree of difficulty for entering and leaving these parking stalls makes this type of parking more suited to all-day parking. This angle is generally not preferred for "in and out" and high traffic lots.

10.3.2 To test the theories found while researching the conventional parking lot industries' arrangements were drawn up with each angle and tested against turning area required to park at the desired angle. AutoCAD drawings for these various angles can be found in Annex W drawing 26. Drawings were completed for $30^0$, $45^0$, $60^0$, $75^0$, and $90^0$. See Table 8 and Figure 26 below for a comparison.

| Dimension | On Diagram | $30^0$ | $45^0$ | $60^0$ | $75^0$ | $90^0$ |
|---|---|---|---|---|---|---|
| **Stall width parallel to aisle** | A | 26.6 ft. | 19.3 ft. | 16.4 ft. | 14.5 ft. | 14.0 ft. |
| **Stall length of line** | B | 60.8 ft. | 52.2 ft. | 46.9 ft. | 43.1 ft. | 40.5 ft. |
| **Stall depth to wall** | C | 30.5 ft. | 36.9 ft. | 40.6 ft. | 41.6 ft. | 40.5 ft. |
| **Aisle width between stall lines** | D | 20.6 ft. | 18.7 ft. | 28.2 ft. | 32.1 ft. | 35.8 ft. |

| | |
|---|---|
| | Largest Value |
| | Smallest Value |

Table 8 Parking layout dimensions for 14 ft wide stalls at various angles.

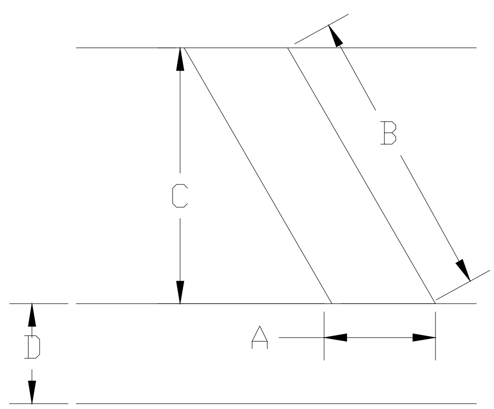



Figure 26 Corresponding Diagram to Table 6.

10.3.3 In consulting Table 6, it was determined that parking the vehicles at a $45^{0}$ would create the most efficient use of space. Although the $90^{0}$ arrangement had the smallest parallel width (A) and stall length (B), it required an aisle width (D) double that of a $45^{0}$ arrangement. While a $30^{0}$ arrangement had the smallest stall depth (C), it had the largest parallel width (A) and stall length (B). It was determined that the angle requiring the smallest aisle width would be the most beneficial to the arrangement.

10.3.4 To optimize the arrangements the vehicles will be parked at 45 angles. There will be a parallel width to the aisle of 20 feet, stall length of 52 feet, a stall depth of 36.8 feet, and an aisle width of 18 feet.

10.3.5 Angled arrangements were completed using three different layouts;

- Vertical lifts/Elevators
- Spiral Ramps
- and a Single Tier layout

10.3.6 All of the AutoCAD drawings are in Annexes V & W. These layouts are discussed in more detail in their respective sections in this chapter.

## 10.4 Air Pallets

10.4.1 The early studies indicated that parallel parking may ‘help’ increase the stowage factor and so in an attempt to maximize the stowage factor in the available area, an air pallet concept was developed. Air pallets are used widely to move heavy loads with relative ease. Following some initial calculations the team concluded that given the maximum weight to be moved i.e. an M1A1 Tank (60 tonnes), that relatively low pressures (~1.56 pounds per square inch for a 60 tonne tank on a pallet measuring 14ftx42ft) were required to move the tank (or truck etc.) transversely across the deck.

10.4.2 However, moving loads on <u>land</u> is a very different problem to moving even modest loads on a ship in a <u>seaway</u> - control of the load is fundamental when on a ship. Lack of time precluded developing this particular concept further than an animation.

10.4.3 Figure 27 shows the air pallets in the cargo hold loaded with 2 humvees and one MTVR.

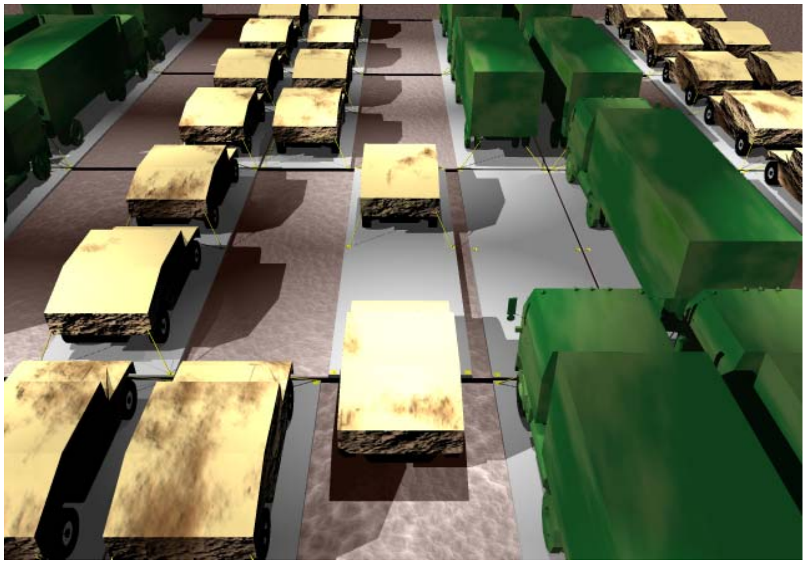


Figure 27 Air Pallets in cargo hold.

10.4.4 The lashings for each vehicle could be incorporated into each pallet thereby enabling more efficient lashing/unlashing to occur in the 'open' i.e. in the access aisle where it is easier to do than between vehicles.

10.4.5 To optimize the arrangements the vehicles will be parked with a stall length of 41 feet and a width of 14 feet. The optimum aisle width will be 14 feet.

10.4.6 Palletized arrangements were completed using three different layouts;

- Vertical lifts/Elevators
- Spiral Ramps
- and a Single Tier layout

10.4.7 All of the AutoCAD drawings are in Annexes V & W. These layouts are discussed in more detail in their respective sections in this chapter.

## 10.5 Vertical Lifts/Elevators

10.5.1 In completing the arrangements, it was determined that the area required for a ramp was extensive and a large driver of a reduced stowage factor. It was believed that elevators would decrease the area required and increase the stowage factor. It was determined that on the palletized system, 4 elevators would be required. Two elevators were placed at each end of the cargo deck in line with each aisle to eliminate additional turning area to enter the elevator. In addition, this was also to increase on load/offload times while still making efficient use of the existing space.

10.5.2 However, only 2 elevators were used in the angled design because there was only room for one aisle. Also, due to the $45^0$ to $45^0$ degree area required to drive around the elevators, there is only space available for 1 elevator at each end of the cargo hold. Elevators will have an entrance and exit door at both ends of the elevator.

10.5.3 It was also determined it would be more efficient in terms of time and space to insert a semi-circle flat deck on deck 1 to allow vehicles to turn around when needed to enter the elevator and offload in the correct direction. Many of the vehicles that were modeled, should not be backed up for long distances.

10.5.4 Turntables were initially discussed as a possibility to eliminate the flat deck space. The turntables were to be inserted in the elevators, but that would have driven the elevator to be approximately 40ftx40ft due to the 40ft length of the assumed vehicles instead of 14ftx42ft. This would increase the footprint required, while also interfering with the turning area required by the vehicles. The turning area required by the vehicles and the footprint of the elevator required by the turn table would cause the beam of the ship to exceed Panama size.

10.5.5 In addition, turn tables will typically be slower than the vertical rise of the elevator, causing the turn table to create a queue at the elevator. Therefore, a semi-circle flat deck was determined to be more efficient than a turn table inside the elevators. Additional area was added to one side of the cargo hold to create an on load/offload area where the vehicle had enough area to turn and drive directly into the elevator.

10.5.6 **Elevator Arrangement: 3 Decks: Palletized 106ft Beam: 4 Elevators** In completing the arrangement for a Panama size ship with 4 elevators and palletized parking, several assumptions were made. The length of the cargo hold was extended to accommodate the turning area for the vehicles to pull around the elevators and turn around in a semi-circle flat deck area directly from their respective aisles. The 106ft beam ship with palletized loaded cargo is not completely optimized. The aisles are wider than necessary to accommodate for the extra beam, but the extra area is not enough to create an additional aisle with additional parking and still have 100% selective offload. The beam would need to be enlarge, which would then exceed Panamax regulations. As a result of this extra aisle space, the stowage factor is affected.

10.5.7 Also note that the stowage factor for decks 2 and 3 are 3.4% higher since there is not a flat deck area for on load/offload or for turning around. Vehicles on decks 2 and 3 are assumed to turn around on deck 1 if needed.

10.5.8 This arrangement was finalized with a beam of 106ft, a cargo length of 455ft, and a total length of 514.4ft. The vehicles were arranged in 4 rows that were 23ft wide, and each vehicle stall was 41ft long. The rows were made up of 7 vehicles. There were also two aisles, both 14ft wide and 4 elevators in the cargo hold. The average stowage factor is 26.7%. Shown in Annexes V & W.

10.5.9 **Elevator Arrangement: 3 Decks: Angled Parking: 106ft Beam: 4 Elevators** As stated earlier, one major change is the use of only 2 elevators instead of 4 for angled parking. In the angled parking arrangement for 3 decks and a Panama size ship, the aisle is also about 10ft wider than necessary to accommodate the extra beam.

10.5.10 However, the space is not large enough to use in an additional parking arrangement. Also, with angle parking, only one aisle is possible per hold due to the size of the vehicles and the turning area required by the vehicles. It is also important to note, that the length is slightly shorter than the palletized version due to the reduction of only one elevator, which creates more usable room for the turning area of the vehicles.

10.5.11 Also note that the stowage factor for decks 2 and 3 are 3.2% higher since there is not a flat deck area for on load/offload or for turning around. Vehicles on decks 2 and 3 are assumed to turn around on deck 1 if needed.

10.5.12 This arrangement was designed to be 106ft in beam, while the cargo area had a length of 446ft and a total length of 522.7ft. The aisle were 28.5ft wide and the vehicle stalls were 36.7ft in depth, 20ft in parallel width, and 52ft in length. There are 2 rows of vehicles with 14 vehicles each, 1 aisle, and 2 elevators. The average stowage factor is 27.3%. Shown in Annexes V & W.

10.5.13 **Elevator Arrangement: 3 Decks: Palletized 91ft Beam: 4 Elevators** The elevator arrangement was initially investigated using the agreed upon beam, 106ft, for a constrained approach. It became apparent, that a 106ft beam did not exhibit optimum use of the space due to the enlarged aisle width in order to maintain that desired beam. So investigations began using the optimum measurements discussed earlier for palletized parking. It was discovered that in order to have 4 rows of vehicles, each 14ft wide, and three parking lanes, also 14 ft wide, and including the area need for turning area and the 4 elevators, the beam would be optimized at 91ft.

10.5.14 However, the aisles are slightly larger than 14ft, due to the turning area required for the vehicles to enter the elevators. Also note that the length of the cargo hold is the same as it is with the Panama size beam. Additional length was not needed. Also note that the stowage factor for decks 2 and 3 are 4.1% higher since there is not a flat deck area for on load/offload or for turning around. Vehicles on decks 2 and 3 are assumed to turn around on deck 1 if needed.

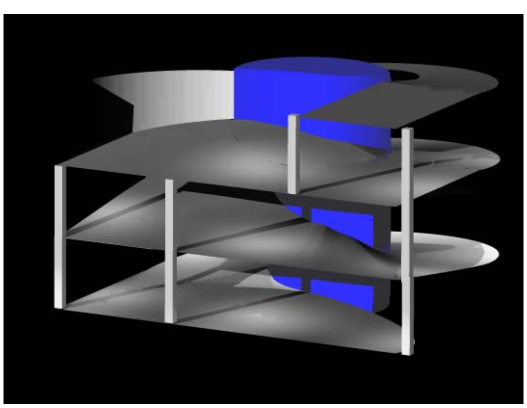
10.5.15 This arrangement was finalized with a beam of 91ft, a cargo length of 455ft, and a total length of 554.3ft. The vehicles were arranged in 4 rows that were 14ft wide, and each vehicle stall was 41ft long. The rows were made up of 7 vehicles. There were also two aisles, both 15.5ft wide and 4 elevators in the cargo hold. The average stowage factor is 31.3%. Shown in Annexes V & W.

10.5.16 **<u>Elevator Arrangement: 3 Decks: Angled 45$^0$ 91ftBeam: 2 Elevators</u>**
It was determined that it is not possible to have an angled parking arrangement on a 91ft beam ship. The aisle width is too small and the area required for the vehicles to make a 45$^0$ to 45$^0$ turn around the elevators from their respective aisles, is too large and exceeds the designated beam. Shown in Annexes V & W.

## 10.6 Spiral Ramps

10.6.1 Spiral ramps are alternative to traditional ramps and indeed to vertical lifts/elevators. The Excel model (see Section 10.11) showed spiral ramps to be ‘quicker’ in enabling Ro/Ro cargo to move between decks than elevators. This is due to the time to load and unload the elevators and the speed of the elevator. In practice, waiting for the elevator to arrive would be an additional delay.

10.6.2 The desire to always be driving forward, lead the team initially to attempt to incorporate two spiral ramps one inside the other (i.e. a double helix). However, a more innovative solution was developed by the team and is shown in Figure 28. Annex J shows 3D solid models of other spiral concepts.



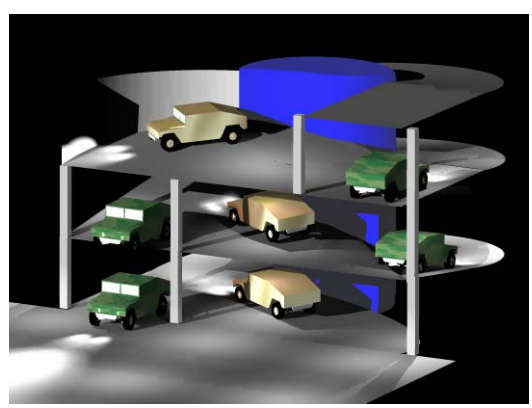


Figure 28 3D Solid Models of Spiral Ramp concept
Note: Brown vehicles going up / Green vehicles going down

10.6.3 It was decided to design arrangements using 2 full spirals and a racetrack design for turning around, and a design that included two ½ spirals. In completing a study involving 3-D designs of the spirals to determine the 2-D footprint for the spiral ramps, it was discovered that the ½ spirals required a beam larger than Panamax regulations allow. So in turn, an arrangement was designed using 1 full spiral and a semi-circle flat deck on each level.

10.6.4 **Full Spiral Arrangement: 3 Decks: Palletized Panama Size**
For this arrangement , in addition to the full spiral on one end of the cargo hold, a semi-circle for turning was also added on each side of the cargo hold.

10.6.5 On the first level, the semi-circle was incorporated into the on load/offload point. The aisle widths are also not at optimum width, thus creating a smaller stowage factor.

10.6.6 Space does not allow room for a $45^0$ to $45^0$ turning area for the vehicles to exit the aisles and enter the spiral ramp while the ramp is still at its optimum size. It was determined that to line up the spirals with the aisles, the beam can not be smaller than 106ft. By eliminating the $45^0$ to $45^0$ turning area, the length of the cargo hold reduced significantly.

10.6.7 Even with the added area for the spirals and flat deck turning area, the overall length is still reduced compared to the arrangements needing the $45^0$ to $45^0$ turns.

10.6.8 There is a beam of 106ft, while the cargo hold has a length of 332ft, and the total deck length is 449ft. This arrangement has 4 rows of vehicles, 7 each and 2 aisles with widths of 23ft. Each vehicle stall has a width of 14ft and a length of 41ft. The spiral deck has a radius of 39ft. The average stowage factor is 31.1%. Shown in Annexes V & W.

10.6.9 **Full Spiral Arrangement: 3 Decks: Angled $45^0$ Panama Size**
As with the palletized arrangement, a full spiral ramp is on one end of the cargo hold and a semi-circle for turning is on the opposite end. The semi-circle was also incorporated into the on load/offload area on the first deck. However, since only one aisle is possible with angle parking, space for a $45^0$ to $45^0$ turning area for the vehicles to exit the aisle and enter the spiral ramp or turn around in the semi-circle had to be added onto each end of the cargo hold. This increased the length significantly and reduced the stowage factor as well.

10.6.10 The aisle width is also not at an optimum width, also due to the turning area required by the vehicles. The area and size of the spiral had to be enlarged to match the vehicle path created by the $45^0$ to $45^0$ turn. As a result, the spiral ramp is not at its optimum size and the beam can not be smaller than 106ft.

10.6.11 This arrangement has a beam of 106ft, a cargo length of 485ft and a total length of 602ft. There are 2 rows of vehicles with 14 each, and an aisle with a width of 28.5ft. The vehicle stalls have a parallel width of 20ft, a length of 52ft, and a depth of 36.8ft. The spiral ramp has a radius of 49.5ft. The average stowage factor is 22.0%. Shown in Annexes V & W.

10.6.12 **2 Full Spiral Arrangements: 3 Decks: Palletized Panama Size**
In addition to adding a spiral deck on each end of the cargo hold, a racetrack shaped aisle was incorporated in the cargo hold to ease

vehicle maneuverability. The on load/offload area is included in the cargo hold in conjunction with one of the semicircles that make up the racetrack aisle. The aisle widths are not at an optimum width, thus creating a smaller stowage factor.

10.6.13 Space does not allow room for a $45^0$ to $45^0$ turning area for the vehicles to exit the aisles and enter the spiral ramp while the ramp is still at its optimum size. It was determined that to line up the spirals with the aisles, the beam can not be smaller than 106ft. By eliminating the $45^0$ to $45^0$ turning area, the length of the cargo hold reduced significantly. Even with the added area for the spirals and flat deck turning area, the overall length is still reduced compared to the arrangements needing the $45^0$ to $45^0$ turns.

10.6.14 There is a beam of 106ft, while the cargo hold has a length of 371ft, and the total deck length is 527ft. This arrangement has 4 rows of vehicles, 7 each and 2 aisles with widths of 23ft. Each vehicle stall has a width of 14ft and a length of 41ft. The spiral ramps have a radius of 39ft. The average stowage factor is 26.8%. Shown in Annexes V & W.

10.6.15 **<u>2 Full Spiral Arrangements: 3 Decks: Angled $45^0$ Panama Size</u>**
As with the palletized arrangement, a full spiral ramp is on each end of the cargo hold and a racetrack aisle is imbedded in the cargo hold. The on load/offload point coincides with the area required for the turn inside the cargo hold. However, since only one aisle is possible with angle parking, space for a $45^0$ to $45^0$ turning area for the vehicles to exit the aisle and enter the spiral ramps was required. This increased the length significantly and reduced the stowage factor as well. The aisle width is not at an optimum width, due to the turning area required by the vehicles.

10.6.16 Since in this arrangement it was necessary to use a $45^0$ to $45^0$ turning area for the vehicles to exit the aisle and enter the spiral ramp and remain at a 106ft beam, the area and size of the spiral had to be enlarged to accommodate for the area needed for the vehicles to exit the aisles and enter the ramps. The area and size of the spiral had to be enlarged to match the vehicle path created by the $45^0$ to $45^0$ turn. As a result, the spiral ramp is not at its optimum size and the beam can not be smaller than 106ft.

10.6.17 This arrangement has a beam of 106ft, a cargo length of 524ft and a total length of 680ft. There are 2 rows of vehicles with 14 each, and an aisle with a width of 28.5ft. The vehicle stalls have a parallel width of 20ft, a length of 52ft, and a depth of 36.8ft. The spiral ramps have a radius of 49.5ft. The average stowage factor is 19.6%. Shown in Annexes V & W. .

## 10.7 Single Tier

10.7.1 The advantage of a single tier arrangement is clearly the removal of the vertical movement of cargo. This 'step' in cargo transfer should not be underestimated. The results of the Excel modeling (see Section 10.11) indicate that the vertical movement of cargo as in a conventional Ro/Ro ship utilizing 3 or 4 decks is penalized heavily during loading and offloading simply due to the time it takes to get the people to the vehicle or stowed position.

10.7.2 In completing initial studies with single tier arrangements, investigations were undertaken to determine the optimum length and width for a single deck to produce the highest stowage factor possible. It was determined that a 172ft beam would be the best choice. This beam optimized both the palletized option and the angled parking option. The length in each design varied and will be discussed in detail in the next few sections. A modified version of the single level angled parking arrangement was applied to the Sea Base Hub ship design.

10.7.3 **Single Tier: Palletized Arrangement**
For the palletized arrangement, 8 rows of vehicles with 10 vehicles in each row, and 4 aisles that are the desired 14ft wide successfully optimized the 172ft beam. Each vehicle stall is 14ft wide and 41ft long. With the additional aisles, a turning area had to be added at each end of the cargo hold so the vehicles could maneuver with ease without backing. An additional on load/offload area was added onto one of the turning areas to allow for vehicles to enter and exit through the 1st aisle. As a result, the flat decks that were added for turning area affected the stowage factor.

10.7.4 The beam is 172ft, while the cargo length is 414ft and the total deck is 518.6ft. There are 8 rows of vehicles with 10 vehicles in each row, and 4 aisles that are 14ft wide. Each vehicle stall is 14ft wide and 41ft long. There is an average stowage factor if 47%. Shown in Annexes V & W.

10.7.5 **Single Tier: 45$^0$ Angled Parking Arrangement**
To optimize the angled parking arrangement, vehicles were arranged along each side and in the center at a 45$^0$ angle. A racetrack turning area was imbedded in the cargo area so the vehicles could maneuver easily, while still using the vacant space created by the racetrack aisle to park vehicles. As a result , 4 vehicles were arranged along one end of the cargo hold to increase the stowage factor and to use vacant space.

10.7.6 Also, along the center, 9 vehicles were arranged in a parallel fashion against the other angled vehicles. This was done to efficiently take advantage of the 172ft beam. The parallel parked vehicles are assumed to be dense packed. It is also assumed that vehicles parked in this spot will be made of those not requiring to be selectively offloaded, like the MTVRs which are all similar. A flat deck area was added to one end of the cargo hold as an on load/offload area. It's shape allows for the vehicles to enter from either aisle to help increase on load/offload times and created additional area for all lanes to exit without forming a queue. The aisles are not completely optimized at the desired 18ft width for angled parking. However, to optimize the layout with the desired beam, the aisles became 20.3ft.

10.7.7 The beam is 172ft and the cargo deck is 530.7ft in length, and the total deck length is 595.5ft. There are 71 vehicles that are parked at a $45^0$ angle, and 9 that are parallel parked. The Angled vehicles have a length of 52ft, a parallel width of 20ft and a depth of 36.8ft. There is one row of the parallel vehicles, with each vehicle stall have a length of 41ft and a width of 14ft. The racetrack shaped aisle throughout the hold has a width of 20.3ft There is a stowage factor of 40.2%. Shown in Annexes V & W.

10.7.8 **Single Tier: $45^0$ Angled Parking Arrangement as applied to a ship design** When the $45^0$ angled parking arrangement was applied to the Sea-Base Hub ship design the length of the arrangement increased while the stowage factor decreased slightly. Several reasons for this include: multiple onload/offload points which eliminated the vehicles parked at the ends of the cargo hold requiring additional length to accommodate the vehicles that needed to be moved, separations and increased deck space for shipboard structures, and an increase in unusable cargo space due to the combinations required of parking spaces, on load/offload, and area lost to angles.

10.7.9 However, the actual design is still considered to be competitive with the theoretical design since the stowage factor only decreased by 2%. However, the aisles are at their optimum width for angled parking.

10.7.10 The beam is 172ft and the cargo deck is divided into two sections, one 420.3ft long and the other 172ft. There are 68 vehicles that are parked at a $45^0$ angle, and 11 that are parallel parked. The Angled vehicles have a length of 52ft, a parallel width of 20ft and a depth of 36.8ft. There is one row of the parallel vehicles, with each vehicle stall have a length of 41ft and a width of 14ft. The 'racetrack' shaped aisle throughout the hold has a width of 18ft. A stowage factor of 38.2% was calculated. Shown in Annexes V & W.

## 10.8 Dispenser Concept

10.8.1 Automated parking garages provided some of the initial inspiration for the Dispenser Concept. These are discussed at Annex G.

10.8.2 A dispenser concept (offering 100% selective offload) is proposed containing cells that are sized for humvees, containers and pallets.

10.8.3 Each cell has been standardized to accommodate one TEU (8ftx8ftx20ft) and so can easily accommodate a humvee (16.4ftx7.2ftx7.8ft) and conveniently can accommodate 20 standard pallets (4ftx4ftx4ft).

10.8.4 A total of 72 stacks are provided, split equally between the port and starboard sides. Each stack has five standardized cells that are located in each demi-hull (arranged one in front of the other) and move vertically using linear induction motors to service the weather deck and the main cargo deck.

10.8.5 The vertical stacks could be moved by a number of different systems for example electric induction motors, or pneumatics, or scissor-jack lifts to name a few.

10.8.6 Scissor-jack lifts are available with collapsed to extended ratios of 1:6 and higher.

10.8.7 Figure 29 shows a picture of a 72,000 Ib scissor jack lift;

*72,000 lb. scissor lift,
Lyric Opera Building,
Chicago, Illinois*

Figure 29 Scissor Jack Lift (72,000 lb capacity)

10.8.8 Figure 30 shows a cut away isometric view of the port side stacks.

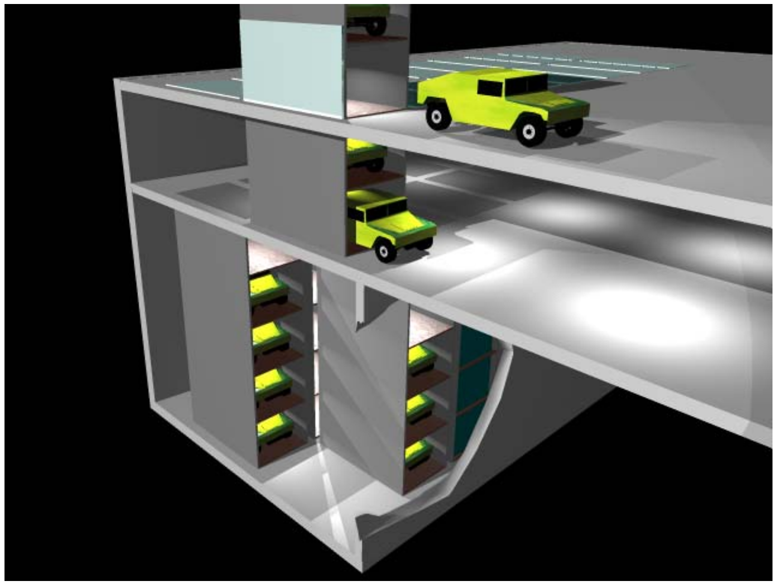


Figure 30 Dispenser Concept within port side demi-hull of Seabase Hub

10.8.9 For the stowage and retrieval of containers an automated system would be required, otherwise the fall-back would be containers with wheels/rollers and a pull/push vehicle.

10.8.10 For the pallets, if 100% selectivity is required, then it is envisaged that each TEU standardized cell would comprise of 10 vertical stacks each capable of moving independently to allow 100% selectivity. Perhaps overly complex but such an arrangement does provide 100% selectivity while providing a very high stowage factor (close to 100%).

## 10.9 Selective Offload remarks

10.9.1 It was concluded that overall, the single level palletized arrangement had the highest stowage factor of 47%. The single level angled arrangement was 40.2% and the angled arrangement as it was applied to the Seabase hub had a stowage factor of 38.2%. In comparing the Panama size-3 deck arrangements, the palletized arrangement with 1 full spiral ramp had the highest stowage factor of 31.3%.

10.9.2 However, it is interesting to note that the angled parking arrangement with 2 elevators had the second highest at 27.3%. The lowest stowage factors came from the angled arrangements for both 1 full spiral ramp and 2 full spiral ramps. Their stowage factors were 22.0% and 19.6% respectively. It is another interesting observation to notice that the palletized arrangement with 1 full spiral ramp had the largest stowage factor of the multiple deck arrangements, while the angled arrangement with 1 full spiral ramp had one of the lowest.

10.9.3 When comparing stowage factors, palletized arrangements create a higher stowage factor in all cases over an angled arrangement, except for in the elevator layouts. See Tables in Annex K.

10.9.4 In all cases, but the elevator arrangements, the overall length of the cargo hold required for angled parking is more than that required for palletized parking.

## 10.10 General comments

10.10.1 The various selective offload concepts investigated here have identified the following high level comments;

- A single level cargo stowage area with palletized parking produces the highest stowage factor of the arrangements tested, at 47.0%.

- If multi-level stowage is desired, palletized parking with one full spiral ramp has the highest stowage factor of those tested, which is 31.1%.

- If angled parking is preferred, a single level deck will be the most beneficial. But if multi-level is desirable, then a layout using 2 elevators per hold with a 106ft beam has a stowage factor of 27.3% and is the largest of those studied.

- An Automatic Stowage and Retrieval System would increase the stowage factor to approximately 80%.

- For comparison and to provide some perspective the stowage factors for current dense packed LMSRs, a commercial Automated Stowage & Retrieval System (ASRS) and a High Speed Sealift (HSSL) trimaran concept are also included on the plots of stowage factors (in Annex K).

10.10.2 The difference in stowage factor between angled parking arrangements and dense packed arrangements facilitated by air pallets, for a given number of vehicles is much smaller than expected. The studies here estimate the difference to be as low as 6.8% in favor of the dense packed option and as high as 9.1%. It is also important to recognize that in the elevator arrangements, the difference was 0.6% in favor of the angled arrangement.

10.10.3 It is worthy of note that the dense packed option here (i.e. utilizing the air pallet concept) still has 100% selectivity. The difference in the palletized arrangements is low due to the number of 'lanes' that are required for the dense packed option to facilitate access.

10.10.4 Table 9 summarizes the results, in terms of stowage factor and offload time, for the range of selective offload concepts considered.

| **Ship / Concept** | **Total number of vehicles** | **Vehicles selectively offloaded** | **Total offload time (single vehicle)** | **Stowage Factor** |
|---|---|---|---|---|
| **LMSR (dense)** | 900 - 1700 | 3 | ~18hrs<br>(NA) | 85% |
| **HSSL (dense)** | 280 | 3 | ~6hrs<br>(NA) | **51%** |
| **ASRS (100%)** | 300 | 300 | ~5hrs<br>(~2mins) | 80% |
| **Dispenser (100%)** | 180 | 180 | ~2hrs<br>**(~2mins)** | **90%** |
| **Single Tier (100%)** | 160 | 160 | ~5hrs<br>**(~2mins)** | **Palletised~47%<br>Angled~38%** |

Table 9. Selective Offload - Stowage Factor and Extraction Times

10.10.5 It is interesting to note that the dispenser concept offers 100% selective offload of all 180 vehicles combined with a very high stowage factor ~90%. Both these attributes i.e. high stowage factor and 100% selectivity are not possible in any of the other configurations investigated apart from the commercial car parking system.

## 10.11 Selective Offload Metrics

10.11.1 Measures of Selective Offload are hard to find. Two significant metrics for Selective Offload are;

- Stowage Factor
- Extraction Time

10.11.2 The AutoCAD layouts enabled accurate stowage factors to be determined for the alternative cargo arrangements. Annex K shows a bar chart detailing the various stowage factors obtained. To provide some perspective, actual stowage factors were added for dense packed vessels such as the LMSR.

10.11.3 For extraction times, the team developed a simple Excel model (see Annex U) to;

- Quantify the extraction times
- Determine the 'bottlenecks'

in order to undertake a quantitative assessment of the different deck layouts and cargo arrangements.

10.11.4 The Excel model used the AutoCAD layouts as the template for each of the three alternative arrangements considered i.e. Single Tier, Decks and Elevators and Decks and Spirals. From the template distances could easily be determined. Assumptions were made regarding speed of elevators, speed of people walking and speed of vehicles in turns and going up and down spirals. The user then defined the steps in the process that a stevedore would go through to offload a vehicle. Sensitivity to position in the hold was investigated simply by varying the associated distances.

10.11.5 Table 10 summarizes the results from the Excel model;

| Arrangement | Min Time (secs) | Max Time (secs) | Average (secs) |
|---|---|---|---|
| Single Tier | 75 | 170 | 123 |
| Decks + Elevators | 140 | 270 | 205 |
| Decks + Spiral Ramps | 95 | 355 | 225 |

Table 10. Summary of extraction times from Excel Model

10.11.6 Of interest, are the following conclusions obtained from the comparative Excel analysis;

- **Single Tier :** dominated by time to get people to stowage
- **Decks+Elevators :** 50/50 split between the time taken to get people to the stowage and elevator evolution
- **Decks+Spirals ;**
    - when deep, transiting through spirals
    - when shallow, getting people to stowage

## 10.12 Recommendations

10.12.1 It is recommended that a single level stowage area be used to stow large vehicles.

10.12.2 Included in the single tier arrangements here, there are approximately 80 large vehicles (or 160 smaller humvees i.e. 2 humvees per MTVR footprint). The MTVR's are typically troop carriers, and are very similar to each other, hence these vehicles could be dense packed in a designated space, or where there is extra space to make efficient use of the area. It is recommended that the remaining 80 vehicles be parked in one of two ways;

- with a palletized arrangement, using 14ft wide aisle and stalls, and optimizing the number of aisles and stalls and length of the stalls in order to optimize your desired beam and cargo hold length

- with an angled parking arrangement, with the vehicles at 45 degree angles and the aisles 18ft wide

10.12.3 Although the palletized version has a better stowage factor, an argument can be made in favor of the angled parking if you consider the design, cost, maintenance and the ship impact of using a palletized system. Therefore, for simplicity, the recommendation would be to use the 45 angled parking arrangement.

10.12.4 The following bullet points are other suggestions for follow on work in this area;

- Create arrangements with 2 move offload and determine stowage factor and compare against 100% complete selective offload.
- Complete more specific arrangements taking in to account exact cargo.
- Complete arrangements by packing for the specific mission.
- Use ICODES loading software to complete more exact and specific arrangements and to evaluate stability of load plan in reference to ship stability.
- Use information gathered and excel model that was created to developed an EXTEND model that will calculate total on load/offload times for the entire ship and identify bottlenecks.

## 10.13 PMS 325 Funding

10.13.1 At NSWC Carderock, Code 2820 is continuing studies concerning selective offload and Re-configurable spaces. Code 2820 is leveraging ongoing PMS325 funding for the Strategic Sealift R&D program. Code 2820 will support the development and evaluation of concepts for reconfiguring spaces for vehicle stowage, high capacity berthing (including bunks, messing, exercise space and hotel services), vehicle maintenance, hospital services, and other feasible uses of empty ship space.

10.13.2 In the selective offload continued studies, Code 2820 will support the development and evaluation of concepts for the handling and stowage of rolling stock and cargo within the seabase to allow for selective offload. Furthermore, this study will identify several concepts for transferring and deploying vehicles and cargo in a seabased environment.

# 11 Re-configurable Spaces

## 11.1 Introduction

11.1.1 Re-configurable spaces, as defined by this report, are spaces which, through minimal modification or impact, can be utilized for a purpose or function other than it's original usage.

11.1.2 In a seabasing environment, space is a valuable commodity; and the ability to reconfigure an unused space for an alternate useful purpose becomes a necessity. Therefore, the ship impacts of integrating modularized/containerized spaces into a ship was examined. It was determined that a cursory investigation of these impacts could be achieved by means of examining current MSC (Military Sealift Command) LMSR (Large, Medium-speed, Roll-on/Roll-off) vessels.

## 11.2 Cargo Holds

11.2.1 To begin the investigation, it was necessary to determine which spaces aboard MSC vessels would be suitable for reconfiguration. It was determined that after offload of MSC vessels, such as the LMSR, and other container vessels, that the best candidates for space reconfiguration consisted of a ship's RORO (roll-on, roll-off) decks, or those decks on which vehicles are stored, as well as a ship's container holds, and weather decks.

11.2.2 Current Bob Hope class LMSR ships offer approximately 380,000 sq ft of cargo space which may be utilized as Re-configurable spaces. Of this space the LMSR offers approximately 5-6 decks of vehicle stowage ranging in height from 7 ft to 21 ft, which offer a variety of space which can be used to store additional functions, such as offices, workshops, medical facilities, etc., and their personnel once vehicles and cargo have been offloaded.

11.2.3 Figure 31 shows a typical Ro/Ro cargo hold.

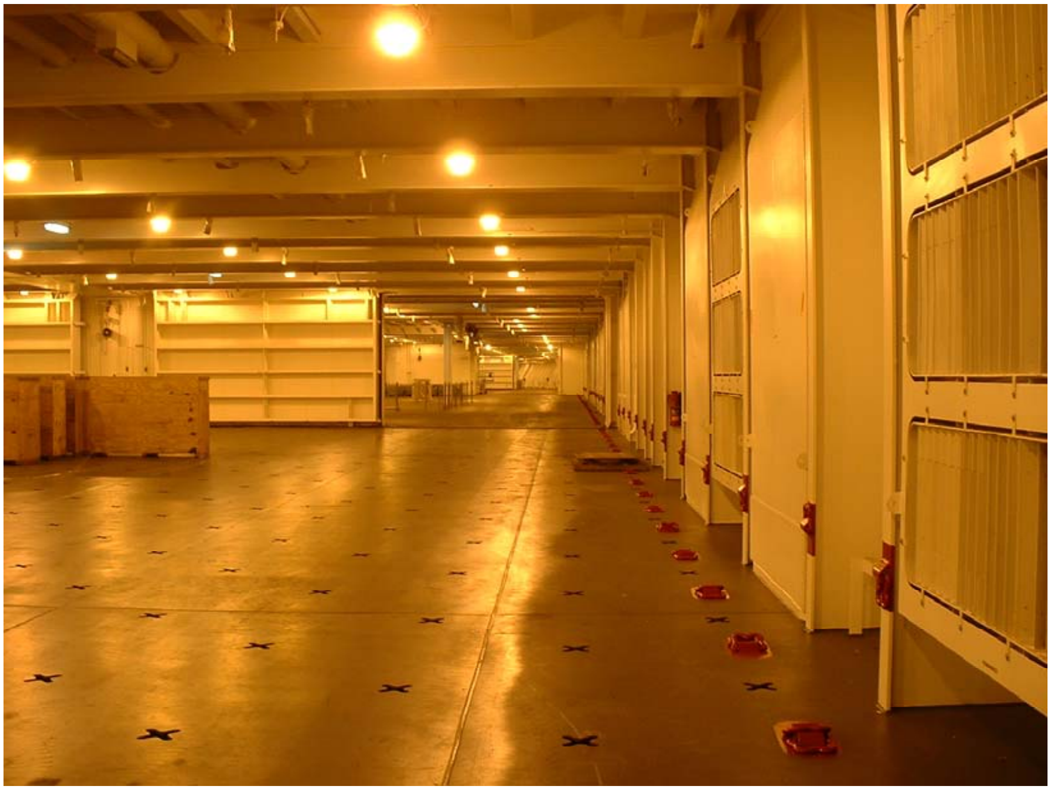


Figure 31. Vehicle stowage deck of Bob Hope Class LMSR

## 11.3 Containers

11.3.1 One potential solution for use in Re-configurable spaces is the use of containerized/modularized spaces. These are spaces that are contained, in compact form, within containers, or other modularized type format. Information obtained from container companies, such as SeaBox, as well as briefings from the Total Open Systems Architecture (TOSA) group at Carderock, who maintain a database of technologies, indicate that there is no limit to the possibilities of containerized spaces.

11.3.2 Figures 32 and 33 show some examples of containerized berthing and shop modules.

Figure 32 Containerized Berthing Modules


Figure 33 Containerized Shop Modules

11.3.3 Currently, there are many companies which produce berthing, offices, workshops, etc., modules. The army also currently makes use of a wide variety of modularized and containerized spaces. In addition, container companies are willing to customize container spaces to whatever specification or need may be required, making these spaces an ideal option for Re-configurable spaces. There are even containers currently built by SeaBox which are designed to Coast Guard Regulations. However, use of these types of spaces creates its own type of unique issues. Among the most important of these is interfacing the modules with current ship systems, as well as any supplemental systems that may be brought aboard. Interfaces are the connections between the module and the ship, and/or other modules. Such support systems as power, ventilation, tankage and hotel services, need to be interfaced with any containers/modules brought on board, in addition to the other support containers and modules that may be brought on board to supplement the ship's current services. .

## 11.4 Matrix

11.4.1 In order to determine the high-level ship impacts that reconfigured spaces would have on current vessels, a spreadsheet was generated to summarize the spaces and services involved with reconfiguration. First, it was necessary to determine which spaces would be a suitable starting point for reconfiguring; as stated previously, it was decided that after offload of MSC vessels, such as the LMSR, and other container vessels, that the best candidates for space reconfiguration consisted of a ship's RORO (roll-on, roll-off) decks a ship's container holds, and weather decks. Once the Re-configurable spaces were determined, a list of the services they provide, or rather, that are present, such as potable water, HVAC, Lighting, etc., was created. Following that, a similar listing was created for possible spaces to be inserted into those Re-configurable spaces, and the services they require to function.

11.4.2 Using these lists a matrix, or spreadsheet, was created comparing spaces to services, see Annex X. Once created, information was gathered to fill in the spreadsheet. Using information gathered from such sources as the General Specifications for Ships of the United States Navy, General Specifications for T-Ships, Accommodation Standards for Military Sealift Command, and the Shipboard Habitability Design Criteria Manual, as well as briefs and interviews with Sealift Group located at Maritime Plaza, LHA(R) and the TOSA group, the spreadsheet was populated.

11.4.3 As the spreadsheet was populated, it became evident that civilian and military requirements were very different in many areas, particularly in berthing and other habitability areas. This indicating that, above all else, a governing requirements document needs to be created for use of MSC ships within a seabasing environment. However, for the purpose of this study, MSC standards were utilized, supplemented by US Navy requirements only when appropriate MSC requirements were lacking. In addition to the requirements issue; it was also apparent that the services available within the above identified Re-configurable spaces provided aboard current vessels are not sufficient to support manned spaces, such as berthing, recreational spaces, medical facilities, etc. Other major impacts illustrated by the spreadsheet are a lack of sufficient hotel facilities to support additional manning, as well as key deficiencies in potable water tankage, sewage, HVAC capabilities, and lighting. For a list of issues see Figure 2. Upon analysis of the spreadsheet, it quickly becomes apparent that ship facilities need to be supplemented along with any additional space added to the ship.

11.4.4 Indicated on the matrix are several key services, as identified by the innovation cell. These are the services shown to the left of the bold line, see matrix. These key areas, although some are indeed provided, are not provided in sufficient quantity to support additional manning. As a result, additional services would need to be brought on board with any added functional spaces, and berthing, or built into the ship. However, in pursuing this option, it would be necessary to size the ship's systems to accommodate an assumed number of personnel, as well as estimating the types of functions that might be brought on board. In modifying the ship for certain functions it would be necessary to develop some standard for interfacing the different space modules, as well accounting for the added personnel each space would bring. For example for each person brought on board to support added functions (shops, medical, offices, etc.) an additional 235 sq ft for officers, and 179 sq ft for crew (based on MSC standards), would need to be added to account for habitability spaces such as berthing, messing, and sanitary spaces. If sizing a ship for a hundred additional personnel (assuming all crew) would amount to 179,00 sq ft of space that would be needed just to support the habitability requirements of 100 personnel. Accordingly, MSC requires 120 gallons per person of potable water storage, which again, for 100 people amounts to 12,000 gallons of added tankage.

11.4.5 This indicates that not only would a significant amount of over-sizing be necessary, but it would also limit the ship's Re-configurable capabilities, as the ship would have to be designed with certain interfacing to support certain assumed reconfigured functions. Alternatively, these support facilities, can be provided via containerized/modularized equipment, but again, a standard format for interfacing the units would need to be designed. For an expanded listing of issues involved with Re-configurable spaces, see Issues.

## 11.5 Issues

11.5.1 Regulations: Need for establishing regulations and requirements concerning the positioning of large numbers of military personnel aboard MSC ships for durations varying from short term to extended.

11.5.2 Establish or create requirements to govern habitability for military personnel aboard MSC ships in sea basing scenarios.

11.5.3 Power Generation: Oversize organic power plant based on estimation of additional personnel and spaces for Re-configurable spaces. Import additional power plants as needed. Need additional ventilation if operating additional generators below the weather deck. Ventilation interfaces need to be considered (tie to ships ventilation or design method for direct venting to weather. May need to isolate generators from nonessential personnel, due to excessive environmental conditions, such as noise from ventilation, heat, etc. Interfaces between generators and spaces requiring power. Applies to both organic and non-organic generators. Power distribution issues include integration of organic and non-organic power and non-organic distribution.

11.5.4 Tankage: Additional Potable water tankage needs to be built into the ship or brought aboard as required. Interfacing tankage with containerized or modularized spaces brought aboard needs to be established. Integration into organic systems. Non-organic distribution. Piping and drainage for these tanks needs to be determined. Integration into organic systems. Non-organic distribution

11.5.5 Waste Management: Additional waste control equipment needs to be supplied, or built into the ship to accommodate additional spaces and manning. Organic sewage and waste tankage needs to be increased, or supplemented by means of containerized tankage to support additional spaces and manning. Interfaces and methodology needs to be developed to allow tanks brought aboard to be evacuated. Interfaces also need to be developed to interact with added spaces and ship facilities.

11.5.6 Hotel Facilities: Adequate reserve hotel facilities need to be designed into the ship. This limits the type and number of Re-configurable spaces to whatever design limit was used. Bringing aboard hotel facilities as needed: Interfaces with ship systems and/or any additional non-organic systems brought on board.

- Potable water
- drainage
- waste
- ventilation
- safety

- communications
- power
- etc

11.5.7 Service Issues: HVAC: Current plants incapable of supporting temperatures on cargo decks necessary for manned spaces.

11.5.8 Additional plants would need to be built into the ship or additional plants would need to be brought aboard in modularized form.

- powering an imported module
- ventilation for AC plants
- distribution systems

11.5.9 Ventilation is adequate in certain modes ("Vent" and "RORO", see Services vs. Spaces Matrix). However, noise levels may be too high for manned spaces. (needs to be studied)

11.5.10 May be acceptable for Shop and maintenance spaces. Would be necessary to build, or modify ship with appropriate ventilation to support manned spaces.

11.5.11 Potable water: Need additional production capacity and/or tankage to support any additional personnel. For each person added, an additional 120 gallons of storage is necessary (MSC Accommodations Manual). Need to modify ship to provide interfaces within cargo holds for any space requiring potable water.

11.5.12 Tankage would need to be brought aboard in containers or the like to support the increase in personnel. Oversized versus non-organic water production systems non-organic system interfaces (sea water, distribution, power, etc)

11.5.13 Fuel: Currently no fuel tankage for vehicles transported

- Additional tankage would need to be added to support maintenance and reconstitution efforts, or additional modularized tankage would need to be brought on board in containers or the like

- Establish distribution systems
- ventilation
- fire/safety
- pollution control

11.5.14 Lighting: With the exception of staterooms, lighting is insufficient within cargo spaces.

11.5.15 Holds would need to be fitted with additional lighting, or additional lighting would need to be brought in depending on type of space to be lighted. Alternatively, containerized space modules with the appropriate lighting levels can be brought on board and

11.5.16 used, above issues still apply. Current lighting levels are suitable for passageways.

11.5.17 Sensors & Alarms: For containerized applications, interfaces to ship's communication and alarms would be necessary.

11.5.18 Fire Control: For smaller manned spaces that are brought aboard as containers, such as berthing and some leisure spaces, where sprinklers are not required, fire plugs and hoses would need to be installed near the access of any such space. If using other forms of reconfiguration, such as collapsible bulkheads to create spaces, adequate fire control is provided by overhead sprinklers

11.5.19 Telephone: No telephone service is provided in cargo bays. Interfaces would need to be added within the cargo bays to support communications. Whether containerized, modular, or erectable options are used, the above requirement remains. For a containerized options however, zones may be set up with interfaces specific to certain space applications, minimizing impact to the ship.

11.5.20 Intercoms, Loudspeakers, and Data: Same as for telephones. However, there are loudspeakers and intercoms within the cargo spaces. Despite this there are no data interfaces, and intercom and loudspeaker connections would probably still need to be added to support added spaces. If containers are used, interfaces would need to be supplied to provide communication and data within the containerized space.

11.5.21 Toilet & Shower: Toilets limited within the hull. For every person placed within non-organic living spaces in the cargo holds, additional space (15 $ft^2$ per person for MSC standards) is needed for sanitary facilities.

11.5.22 The ship would need to be modified with additional sanitary facilities for a predetermined amount of personnel, or containerized facilities would need to be brought in to support the personnel added by the spaces placed in the cargo holds.

11.5.23 Non-organic sanitary facilities would also require ventilation modifications to either vent directly to the weather, or into the ships current ventilation system.

11.5.24 Waste Management: Capacities of organic sewage tankage and waste treatment plant would need to be sized for organic plus non-organic personnel.

11.5.25 Alternatively, additional tankage and waste treatment plants can be brought on board within containers to offset the additional load of added personnel.

11.5.26 A method to empty, or replace tanks brought aboard would also need to be devised, as well as a method to dispose of it.

## 11.6 Military Benefit

11.6.1 Despite the issues involved currently with Re-configurable spaces, the military benefits are substantial. First, and foremost is the ability to keep MEB forces' equipment, personnel, maintenance, and supply away from threat in a secured seabasing environment. By reconfiguring unused spaces to such things as maintenance bays, berthing spaces, medical facilities, etc., the need to maintain and supply those same services on the beach, become nonexistent. An addition, additional security personnel to maintain the 'beach' are not needed, as the typical 'beach' functions are located within the secured seabase. An added benefit of reconfiguring spaces lies within the potential for reconstitution efforts. With a secure supply line to the seabase, and the ability to perform certain maintenance tasks, MEB forces can return from one mission, and be re-supplied and rearmed, and deployed to their next mission

## 11.7 Recommendations

11.7.1 With the information gathered, the most evident fact is the need to develop general, and habitability requirements for military personnel on board MSC ships during a seabasing scenario. Current sizing requirements for MSC are liberal in the space that is allotted to personnel. If sufficient amounts of personnel and functional spaces are to be utilized; the current MSC requirements would require substantial ship impacts, which can be alleviated by creating requirements more in line with current navy specifications.

11.7.2 Further work must also be conducted into the area of interfacing. Consideration needs to be put into categorizing space functions in terms of what interfaces would be needed. In addition to categorizing interfaces, attention needs to be given toward generating standard interface requirements. This would allow for customization of current container technologies to Navy capabilities, by providing a variety of commercial vendors the ability to develop and provide modularized functional, and support spaces to an array of seabasing scenarios, that can be interchanged with ease within theatre.

# 12 Advanced Logistics Delivery System (ALDS)

## 12.1 Concept and Modes of Operation

12.1.1 During a progress meeting with the sponsor, Admiral Cohen requested that the team give some consideration to concept(s) that looked towards the 2020 timeframe and encouraged the team to think more innovatively. Given limited resources, the team have included a concept known as the Advanced Logistics Delivery System (ALDS) that was developed by a previous innovation cell at NSWC Carderock.

12.1.2 The Advanced Logistics Delivery System (ALDS) is a concept that utilizes inflatable wing technology. Loads are launched by a catapult to an altitude from which they simply glide (via inflatable wings) to their destination point. ALDS bypasses the JLOTS environment by projecting gliders from a ship over the beach to an altitude from which they glide to their target destination.

12.1.3 Figures 34 & 35 shows the ALDS concept ship and glider respectively;

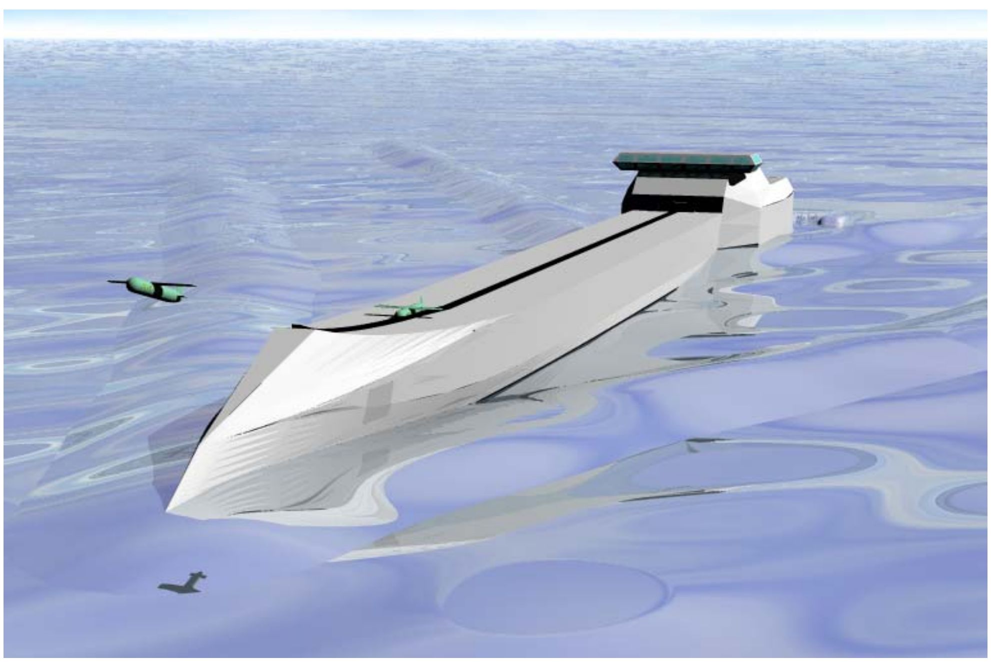


Figure 34. ALDS gliders being launched

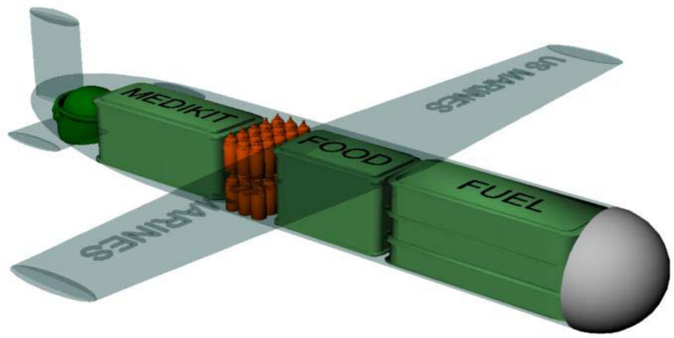



Figure 35. ALDS 'glider'

12.1.4 Characteristics of ALDS include;

- Launched at 500 knots to 7,500 feet
- Range 26 nm
- Payload 1000 lbs
- Delivery rate 15 ST/hr
- Glides at 100 knots
- Cost $12.6k each
- Ability to 'service' 7200 square miles per day
- Ability to rapidly reposition at short notice
- Difficult to target
- Low delivery cost per tonne

## 12.2 Cost Model

12.2.1 A simple cost model has been developed to allow cost comparisons between ALDS, MTVR trucks, V22 Osprey, UH-1Y and CH-53E helicopters. The costs estimated are solely for fuel and personnel to deliver 105 tonnes of cargo. An on-road and off-road calculation has been included for the trucks.

12.2.2 The cargo load of 105 tonnes was derived from one Landing Craft Utility (LCU) load of MTVR trucks and escort vehicles. An LCU can carry two humvees and seven MTVRs which in turn can carry 15 tonnes of cargo each, hence 105 tonnes.

12.2.3 It has been assumed the MTVRs would be escorted front and rear by two humvees. The LCU can fit 7xMTVRs and 2xHumvees on its main deck. The all up weight of the vehicles and their cargo is 210 tonnes much less than the 350 tonnes maximum capacity of the LCU 2000.

12.2.4 The assumed mission profile for the options investigated are as follows:

- LCU transits 10 miles to shore then MTVRs transport cargoes 15 miles inland to the objective (total distance 25nm each way)
- V22 Osprey, UH-1Y or CH-53E helicopters transport cargo from suitable vessel 10 miles offshore to an objective 15 miles inland, utilizing maximum internal payload and making journeys as required to achieve objective
- ALDS system deploys gliders as necessary to transport cargo from ship offshore to inland objective, these are one way journeys for each glider

12.2.5 In addition to the assumption of mission profiles the following detail assumption were made to address the particular requirements of each system and to gain a level of broad equivalence;

- helicopters and V22 operate in flights of two with a further aircraft of the same type acting as an escort
- Fuel consumption figures for the air assets are not modified to include the increase in efficiency afforded when flying the return leg of each journey
- The hourly rate is increased by a factor of three for pilots and crew of air assets over that of crew of LCU and MTVRs
- The cost of replacing ALDS gliders is not accounted for
- The time lost to refueling is not accounted for

12.2.6 Table 11 below summarizes the results;

| | LCU-MTVR On-road | LCU-MTVR Off-road | UH-1Y | CH-53E | V22 | ALDS |
|---|---|---|---|---|---|---|
| Total Crew Cost ($) | 977.54 | 2819.36 | 3483.33 | 803.33 | 725.85 | 840 |
| Total Fuel Cost ($) | 255.39 | 940.04 | 8944.62 | 8275.86 | 7116.34 | 384.85 |
| Cost per Ton Payload ($) | 11.74 | 75.64 | 118.36 | 86.47 | 74.69 | 11.67 |
| Cost per To | 3.46 | 9.64 | 12.23 | 38.75 | 37.04 | 1.67 |
| Fuel per Ton Payload (gal) | 0.45 | 0.82 | 28.4 | 26.27 | 22.59 | 1.22 |

Table 11. Cost Comparison of ALDS, Trucks & Helicopters

12.2.7 The off-road cost per ton payload are approximately 6 times greater than the on-road costs ($75.64 versus $11.74) because of;

- the need to travel slower
- increased fuel consumption off-road
- axle weight more than halved when going off-road, hence need for repeat trips to deliver the same load

12.2.8 Assuming a 70/30 split for off-road/on-road missions then the delivery cost per tonne for land vehicles is ~$56.47. This is significantly lower than that of all the air systems except ALDS which is remarkably low at $11.67.

12.2.9 For air assets the cost is broadly similar, however the smaller UH-1Y helicopter suffers a penalty due to its limited payload capacity.

12.2.10 The ALDS system was found to be very effective in terms of cost, however this must be seen as costs for a 50% efficient system, neglecting losses in power generation etc.

12.2.11 The cost model is simple, and does not factor in the working hours of the people and their availability. Similarly the costs associated with procurement, maintenance, reliability etc are not accounted for, these factors would only increase the costs incurred.

## 12.3 Military Benefit

12.3.1 ALDS provides;

- Direct ‘seabase-to-foxhole’ logistics support, bypassing JLOTS
- Seabased sustainment of STOM/OMFTS beyond 250nm
- Alternative to valuable air assets which could be relieved of logistics duties in favor of reconnaissance and war-fighting

## 12.4 Recommendations

12.4.1 There are many high risk areas with this concept and hence further development is necessary. The primary concerns are;

- Bearings for the catapult
- Optimal design of delivery vehicle
- Use of inflatable wing technology

12.4.2 It is also likely that increased range and payload characteristics would be considered operationally essential. Ranges of 25-250 nm and payloads of 1000-5000 lbs need to be considered.

# 13 Management System

## 13.1 System Infrastructure

13.1.1 One of the fundamental problems with the identification of the requirements for a Seabase management system is that the composition of the Seabase is not defined. As a result, the proposed solution must be deployable across a range of solutions.

13.1.2 The most fundamental requirement of any computer system in this environment is the ability to continue operations with the loss of multiple constituent elements. It must be assumed that the Seabase would be a target for hostile action and, as a result, losses would be taken. Therefore, the only possible solution to this requirement would be to utilize a distributed, decentralized server architecture with a server node located within each element that constitutes a part of the Seabase. With the data and processing power distributed across the entire Seabase, the system will continue operation with the loss of all but one of the Seabase Elements. As a result, this design is applicable to all possible Seabase designs.

13.1.3 The use of a distributed architecture, however introduces different problems. The most fundamental is data assurance, ensuring that data is consistent and correct across all system servers. The solution is for each element to maintain data only relevant to the equipment/cargo stored within that element. If data associated with equipment stored within other Seabase Elements is required, this information is retrieved directly from the storing Seabase Element.

## 13.2 System Identification of Seabase Cargo

13.2.1 The value of any computer system is proportional to the accuracy and timeliness of the data held within the system. Therefore to ensure that the computer system fulfils its requirements the equipment that is transferred around the Seabase environment must be accurately tracked. Current military tracking systems operate at the Container level, by tracking the location of container using Radio Frequency Identification (RFID) tags. Individual items can only be tracked by locating the container they are transported in. Unfortunately this level of granularity is not adequate for the tracking and monitoring of the items within a Seabase Element. To solve this RFID tags should be located within/on each item to be tracked.

## 13.3 Introduction to Radio Frequency Tags

13.3.1 There are three types of radio frequency tags;

- Passive (see Figure 36)
- Semi-Passive
- Active


Figure 36. Passive RF Tag (US quarter for size)

13.3.2 Passive Tags are the cheapest and least sophisticated RFID tags available. They possess no internal power source and must use the power they receive from a transponder's signal to power its own signal. Therefore they are only capable of transmitting information after being requested by a transponders or reader. They are capable of being read from, or written to, up to a distance of 10 meters.

13.3.3 Semi-Passive Tags are identical to Passive tags except they posses an internal power source. This allows them to transmit over larger distances, approximately 100 meters, however, as with Passive tags they do not transmit information unless a reader has interrogated them.

13.3.4 Active Tags possess an internal power source, as with Semi-Passive Tags, however they can transmit information without being activated by a reader. They have much greater ranges than Semi-Passive tags, with the ability to transmit over several kilometers.

## 13.4 Network Proposal

13.4.1 Within the Seabase environment there is a requirement for two levels of accuracy with regard to locating items. Within a Seabase Element the requirement is to locate an item with a high degree of accuracy, e.g. within a meter, whereas for items stored within another Seabase Element, the Global Positioning System co-ordinates of the element are sufficient.

## 13.5 Seabase Environment Tracking

13.5.1 There are two requirements for the system within the overall Seabase Environment.

- Identify new equipment entering the environment aboard various vessels
- To locate an item on a Seabase Element

*13.5.2* The identification of new equipment entering the Seabase Environment can occur by radar detection of the transport vessel. When the transport vessel is identified via radar by one of the Seabase Elements, the Seabase Tracking commences. One of the Seabase Elements is tasked to communicate with the new vessel to identify the cargo it is transporting, identify it's requirements (e.g. space, services) and to communicate with the other Seabase Elements to decide which is the best equipped to process and store the new equipment. The vessel receives this information and then docks with the appropriate Seabase Element.

## 13.6 Seabase Element Tracking

13.6.1 Within each Seabase Element, there would be two distinct RFID transponder/receiver networks. These are;

- A network to detect when items enter and exit the Seabase Element
- A network to track an item within the Seabase Element

13.6.2 The first network is used to detect when items are transferred to and from other delivery vessels. This can be achieved by placing transponders/receivers within all loading bays in a configuration that ensures that all items must pass near the transponders/receivers when they are loaded and unloaded from transfer vessels.

13.6.3 The second network requires that the storage areas, within a Seabase Element, be fitted with RFID transponders/receivers that are used as a Local Positioning System (LPS) to precisely track the location of each item. The transponders are fitted within the storage areas in such a way that every location is within the range of at least three transponders. This means that each location is within the maximum transmitting distance of the transponders. To identify the precise location of an item, the item's RFID will transmit its unique identification code. This code will then be detected by at least three transponders that will report the bearing of the signal back to the computer system, which then calculates the position of the item.

13.6.4 There are two different methods of utilizing the LPS in locating required items;

- Real-Time Tracking
- As-Needed Tracking

13.6.5 Real-Time Tracking stores the current position of each item, while As Needed Tracking locates an item when its location is required.

13.6.6 With Real-Time Tracking the item identifies itself to the installed transponders at regular intervals. While this tracking method allows the element's computer system to maintain a real-time record of an item's position within the Seabase Element it imposes high performance requirements. With the number of items stored within a Seabase Element likely to be significant, the transponders/receivers installed must possess the ability to process several hundred items a second at a minimum.

13.6.7 This required process rate is, however, likely to be much higher than this, at a rate greater than current technology is capable of supporting. This system would also require a computer system capable of processing, potentially, thousands of transactions a second, while still performing other functions. This impacts on both processor speeds and storage capabilities. However, this system allows for the use of all types of RF tags including the less expensive passive tags.

13.6.8 As-Needed Tracking removes the requirement to store positional information on each item within the Seabase Element. This system tracks what items are stored but not their storage locations. To locate an item the system follows the following procedure;

- The System broadcasts a request containing the required items unique RFID code
- Each tag receives the request and checks it received code against its code
- The correct RFID tag then transmits its signal
- The system detects the transmission and identifies the item's location

13.6.9 As-Needed Tracking is advantageous to Real-Time Tracking due to the potential reduction in system requirements for system processor speed and storage requirements. However, the intelligence required within the tags for the system to operate may prevent the use of passive tag technology. This depends on the power requirements needed to perform the required computational requirements and the tag's efficiency at power generation from the received transponder signal.

13.6.10 The technology adopted for the tracking of equipment within a Seabase environment can be different for each Seabase Element as the operate independently of other Seabase Elements. Therefore, as the RFID tag technology develops, these developments can be incorporated into each element during the designs, substantial upgrades or ad-hoc upgrades to just the tracking system.

13.6.11 Different aspects of the system limit each type of tracking. With As-Needed Tracking, the limit is imposed by the maximum read rate of RFID readers. As this is used to locate an item when it is required, this has the potential to limit the response rate to any query that requests the location of an item. Current research at the Pacific Northwest National Laboratory has produced readers that can read 500 tags simultaneously. Whether this rate is suitable can only be determined with testing in a simulation environment.

13.6.12 The speed limit for Real-Time Tracking is the speed of update to the system when an item is moved. While the update speed is dependant on the speed of the computer system, the type of logistics used will also impact on the performance of Real-Time Tracking.

13.6.13 There are two primary types of logistics; Just-in-Time and Just-in-Case. Just-in-Time logistics maintains a minimum level of supplies, which is frequently replenished. Just-in-Case logistics maintains a larger level of supplies, which is the replenished less frequent. This impacts Real-Time Tracking as Just-in-Time logistics imposes a greater flow rate, i.e. the number of items passing through the seabase per time unit, which requires a greater number of system updates, than Just-in-Case logistics, where supplies may remain in the one location for a longer duration.

13.6.14 As a result of the unknown logistic environment it is difficult to identify which solution is the preferred option for tracking supplies and equipment through the Seabase. However, as both Radio Frequency Identification and their supporting computer systems are being actively researched by various industrial sectors and military organizations. These parties will continue to fund the research and development of the required technologies; therefore they should not require further research funding.

## 13.7 Management System Security

13.7.1 An important consideration in the design of the Seabase Management System is ensuring that all data is secure and accessible by authorized personnel only. There are two areas of consideration;

- Security within the Seabase Element
- Secure communications between the Seabase Element and external Systems

13.7.2 Seabase Element Security - Security within the Seabase Element should ensure that only authorized Personnel should have the ability to access and modify the data stored within the Management System.

13.7.3 To enable this capability the security infrastructure should provide the ability to restrict access and capabilities dependant on the user and their locations. Therefore, an authorized user may have permission to both read and modify data, however, the ability to modify the data may be dependant on their location and access method.

13.7.4 Secure Communications - The need for secure communications is inherent in most military environments. This is also the case for the Seabase Environment. The main requirement within the Seabase Environment will be communications with organizations external to it. For communications within the Seabase Environment, while secure communications are preferable, this capability may not be required as it should be assumed that the internal Seabase Environment communications with be of limited range and hostile forces will not be able to enter within the range of the internal communications due to the protection afforded to the Seabase Environment.

# 14 Naval Architectural Issues & Features

## 14.1 Overview

14.1.1 The development and assessment of the various concepts and enabling technologies coupled with the team's understanding of seabasing concepts such as Ship To Objective Maneuver (STOM), Operational Maneuver From The Sea (OMFTS) and so on, enabled the team to identify four key global naval architectural issues of seabasing.

14.1.2 Of course there are a large number of more specific naval architectural issues. A list of these is included at Section 14.4. It should be noted that the list is neither comprehensive nor ordered.

14.1.3 Having identified the specific and global naval architectural issues, the key aspects of the concepts that address these issues were then highlighted. These are discussed in Chapter 16.

## 14.2 Seabasing - Global Naval Architectural Issues

14.2.1 The four global naval architectural issues identified are;

- Interoperability with commercial vessels;
- NA requirements differ significantly in each Seabasing Phase;
- Integration of Logistics with Naval War-fighting;
- Fleet wide NA impacts significantly affected by Seabasing choices

14.2.3 Taking each of these in turn;

14.2.4 **Interoperability with commercial vessels**. STOM and OMFTS concepts intend to minimize or indeed remove entirely the logistics footprint ashore i.e. the 'iron mountain'. This fundamental change in warfighting will dictate an increased transfer of materiel at-sea just in time for delivery ashore.

14.2.5 At-sea transfer is likely to involve packaging in the form of pallets and containers (TEUs : Twenty-foot Equivalent Units) - unlikely to be 40ft containers although there is a move towards increased use of 40ft containers in the commercial world.

14.2.6 Coupled with this is the sustainability of the seabase and so it may be concluded that the future seabase is very likely to need to operate with commercial vessels particularly containerships.

14.2.7 Currently, most containerships do not carry their own cranage relying instead on port facilities. So future seabased logistics ships are going to need container capable cranage that can be operated in higher seastates to ensure the continued sustainment of forces ashore.

14.2.8 In addition, commercial Ro/R0 ships have a ramps that do not slew. This may or may not be a problem depending on the loading / offloading situation however should not be forgotten.

14.2.9 **<u>NA requirements in Seabasing Phases</u>**. As the phase of the seabase shifts the naval architectural issues change. In particular there are significant changes in the type of materiel to be transferred, in the quantity of materiel to be transferred, in the rate of transfer and the demands on the ship systems will have to react to meet the demands.

14.2.10 Re-configurable spaces and selective offload features within a design will ensure these different attributes are more effectively met thereby reducing the risk of unwanted or unplanned drops or pauses in the operational tempo.

14.2.11 **<u>Integration of Logistics with Naval Warfighting</u>**. An example of this is the current MPF(F) designs. These vessels are becoming more and more general purpose i.e. they carry lighters on deck, have cranes, have large and expensive well decks, carry vehicles etc. At least some of these features would be better off in role specific seabased logistics ships.

14.2.12 This would allow the general purpose vessels to become more role specific. They would be smaller, hence more affordable, more agile and more effective war-fighting assets.

14.2.13 **<u>Fleet wide NA impacts affected by Seabasing choices</u>**. A part from MPF(F), there is little or no other seabasing effort focusing on the platforms. The danger is that the inertia and conflicts that MPF(F)face and the outcome of these design deliberations within MPF(F) may steer the wider seabasing forum down the wrong path. Seabasing is NOT about one single platform - it will require a collection of logistics and war-fighting ships that are complementary and work effectively as a system. Flexibility and adaptability are key attributes.

14.2.14 The decision not to have dedicated craneships, such as the deep water stable craneship proposed here, will require cranes to be fitted on a large number of other vessels. The cranes on these vessels then have to be maintained and ‘carried’ around the ocean even when not required. Dedicated craneships could be stored undercover and brought out when required.

## 14.3 Seabasing - Specific Naval Architectural Issues

14.3.1 In addition to the global naval architectural issues identified and discussed in Sections 14.1 & 14.2, a number of more specific NA issues were identified at various stages.

14.3.2 A bulleted list is included here for completeness. It should be noted that this list is not considered to comprehensive nor in order of priority;

- ramp cracking due to torsional and / or sideways movement of the ramp
- crane pendulation
- relative motion
- personnel safety
- control of ships and lighters at slow speed
- container handling and transfer
- transfer of rolling stock at sea in higher seastates
- lack of marinized cranes of sufficient reach, capacity and high transfer rates
- need for accurate seakeeping tools to predict relative motions in high seastates in a multi-platform environment at zero speed
- integrated dynamic positioning systems
- in heavy weather, cranes can keep working longer than ramps and in addition the materiel demands of a seabase dictate that cranes are required more often than ramps

# 15 'Cartoon'

## 15.1 Seabased Logistics

15.1.1 Rear Admiral Cohen set us the task of producing our own cartoon i.e. a pictorial version of our concepts within a seabase. The picture below is such a cartoon.

15.1.2 The platforms are small and hard to recognize, which is why the team chose to produce an animated cartoon. An animation was produced for each of the concepts and enabling technologies developed here.

15.1.3 A CD containing the animations is available on request.

# 16 Conclusions

## 16.1 Overview

16.1.1 This report documents the 14 week effort undertaken by the Seabasing Innovation Cell, part of the Centre for Innovation In Ship Design (CISD) at the Naval Surface Warfare Centre - Carderock Division.

16.1.2 The sponsor for the work was Rear Admiral Jay Cohen, the Chief of Naval Research.

16.1.3 The focus of the work was the Transfer of Goods at sea, in particular identification of the naval architectural issues.

16.1.4 The team developed a range of concepts and identified the technology development needs to fully exploit the concepts.

## 16.2 Concept Conclusions

16.2.1 In total four concepts were developed and assessed, namely;

- Intermediate Transfer Station (ITS)
- Deep Water Stable craneship
- Seabase Hub
- Advanced Logistics Delivery Ship (ALDS)

16.2.2 Seven Enabling Technologies were investigated, namely;

- Selective Offload
- Re-configurable Spaces
- Seakeeping
- Materiel Management System
- Dispenser Concept
- Air Pallet Concept
- Spiral Ramp Concepts

16.2.3 There are some high risk areas with some of the concepts developed. Further work is required to investigate these areas and to de-risk the concepts.

16.2.4 Having identified the specific and global naval architectural issues, the specific naval architectural features of each the concepts and enabling technologies are bulleted here for clarity.

16.2.5 The features are bulleted under the associated concept heading;

**Intermediate Transfer Station (ITS)**

- Inter & Intra theatre delivery platform
- Uses existing capability to provide efficient at-sea transfer of vehicles

**Deep Water Stable Craneship**

- Extends crane transfer through SS5
- Provides Container transfer capability
- Reduces fleet wide cranage requirements
- Increases interoperability with commercial vessels

**Seabase Hub**

- Enables effective reconfiguration / reconstitution within Seabase
- Reduces burden of requirements throughout Seabase

**Advanced Logistics Delivery System (ALDS)**

- Direct Seabase to Foxhole logistics support
- Enables Seabased sustainment of STOM/OMFTS beyond 250nm
- ‘Relieves’ valuable air assets for other duties

**Dispenser**

- Provides 100% Selective Offload with very high Stowage Factor

**Re-configurable Spaces**

- Enables multi-rolling with one Seabased platform
- Improves flexibility and adaptability of Seabase.

## 16.3 Global Conclusions

16.3.1 The main conclusions are highlighted by the need to consider;

- Interoperability with commercial vessels
- NA requirements differ significantly in each seabasing phase
- Integration of logistics with war-fighting
- Fleet wide NA impacts are significantly affected by seabasing choices

## 16.4 Generic Conclusions

16.4.1 A visible and coordinated Seabasing effort needs to be maintained. Many organizations and authorities are reported to be investigating aspects of seabasing yet it is difficult to determine what they are doing and who they are liaising with. Authorities need to communicate their work more widely.

16.4.2 Good seakeeping characteristics of seabased platforms enables effective seabasing.

16.4.3 Seabasing is likely to demand a much higher utilization of assets. The fleet need to consider this in terms of maintenance scheduling and availability of personnel. It is likely that in-theatre maintenance will be required. The large deck of the ITS could be used as an emergency or indeed scheduled dry dock facility for both lighters and smaller, limited range vessels and larger war-fighting and logistics ships.

16.4.4 Seabasing is an immense area with far reaching impacts in almost all naval vessels. Decisions made today on new classes of ships will directly influence the design of follow on platforms and the effectiveness of the future seabase when it is assembled and operated. Careful consideration should be given to the provision of a few key seabasing logistics assets. Often the effectiveness of the operational campaign will be determined by the effectiveness of the logistics. Get the logistics right and the job can often be completed much quicker and with a higher operational tempo.

16.4.5 In terms of stowage and retrieval, it is not clear to the team whether stowage factor or extraction time is the primary requirement, or do they share an equal percentage? Selectivity can be reduced by incorporating one and two moves to get to the specific cargo or by selecting any vehicle rather than a particular vehicle. Much of this depends on how the materiel is to be packaged for the war-fighter. Here, 100% selectivity was investigated to provide the opposite boundary to currently dense packed ships, thereby allowing the ship impact (in terms of deck area) to be determined. A volumetric stowage factor was not determined here.

16.4.6 Single tier arrangements greatly assist with extraction times, but there are no clear indications of how quickly materiel is required.

# 17 Recommendations

## 17.1 Concept Recommendations

17.1.1 The identified Technology Development items largely fulfill the concept recommendations, namely to investigate the;

- hinging mechanism of the deep water stable craneship
- operating and control systems for the dispenser and air pallet concepts within the seabase hub
- multi-vessel station keeping for the Intermediate Transfer Station
- seakeeping performance of the med-moored configuration in different seastates and headings
- size and shape of the spar of the deep water stable craneship
- thruster sizing of the deep water stable craneship
- powering of the deep water stable craneship in the spar and hull borne modes
- integration of multi ship dynamic positioning systems particularly in the med-moored configuration as per the Intermediate Transfer Station
- bearings for the ALDS catapult
- optimal design of delivery vehicle for ALDS concept
- use of inflatable wing technology for ALDS gliders
- options for increasing range and payload of the ALDS gliders
- consider ranges 25-250 nm and payloads 1000-5000 lbs

## 17.2 Generic Recommendations

17.2.1 The general recommendations from this work are to continue to study seabasing and its impacts. Generic recommendations include;

- Modeling of the operational effectiveness of the particular concepts (through war gaming) to determine the increase in capability and/or operational tempo

- Communicate the output of this work to the wider defense community to seek feedback

- Seek Industry views of the proposals, particularly the offshore industry

- Speak to operators of lighters and larger platforms (both military and commercial) and seek their perspective / comments

# 18 Acknowledgements

## 18.1 Internal

18.1.1 The team is very grateful to the sponsor, Rear Admiral Cohen for funding this work. The team has learned a great deal about the current problems associated with the transfer of goods at sea while developing a wide and deep understanding of seabasing. The main issues and challenges that seabasing present are now, more clearly understood by the team.

18.1.2 In addition, the team is grateful for the opportunity to work in such an unconstrained manner (while being mentored) on a real, high profile and current problem.

18.1.3 Within Carderock and key to the team, special thanks go to Dr. Colen Kennell for his knowledge, direction, advice and 'bright ideas'. The team would also like to thank Mr. Art Rausch, Mrs. Kelly Cooper, Mr. Jason Strickland, Mr. Jack Offutt and Mr. Owen Ritter for their support and guidance.

18.1.4 Particular thanks to Mr. Tim Smith who completed the Seakeeping studies in a very short timescale. In addition, the Total Open Systems Architecture team (TOSA) are thanked for sharing their work.

18.1.5 External to Carderock, but within the US Government, thanks go to Mr. Keith McAllister, Rear Admiral Mal MacKinnon (retired), Mr. C.F. Schneider and Mr. Steve Wynn for their advice and guidance.

## 18.2 External

18.2.1 The team would like to thank Mr. Mike Resner, Mr. Andy Bush KBR Haliburton, Mr. Mark van Meel President of NMA and Mr. Bob Scher, JJMA.

18.2.2 The team would like to thank Garden Street Parking Garage in Hoboken, New Jersey and Summit Grand Parc Parking Garage in Washington DC for sharing details with the team of how their systems operate.

18.2.3 The UK Ministry of Defense (MoD) are acknowledged given their continued sponsorship of a UK Naval Architect to work in the US under secondment to the UK's Defense Science and Technology Laboratories (Dstl). The UK/US Engineering and Scientists Exchange Memorandum (ESEM) is the mechanism under which this exchange takes place.

18.2.4 The team is grateful to the UK Ministry of Defense Graduate Recruitment (x-DESG) and Training Program who continue to see the great value in sponsoring two UK graduates on six month training placements at NSWC Carderock.

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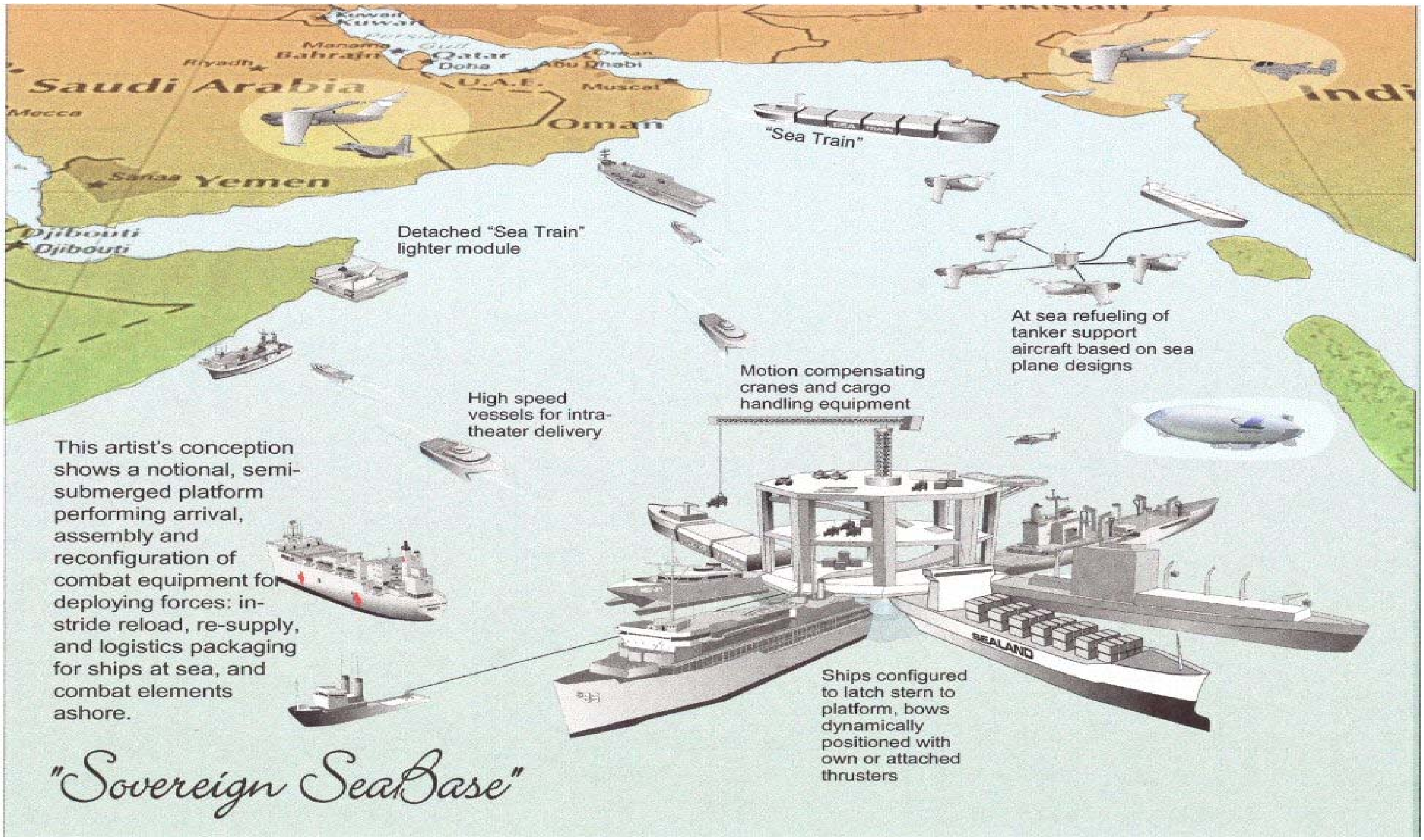
31. ALDS (see Jason Strickland)

# 20 Annexes

## Annex A - Rear Admiral Cohen's vision of Seabasing

20.1.1 Rear Admiral Cohen (Chief of Naval Research) has produced a graphical depiction of a future seabase as shown here;



## Annex B - Seabasing Innovation Cell : Team members

20.1.2 The Seabasing Innovation Cell team members ;

| | Team Member | Discipline | Affiliation |
|---|---|---|---|
| 1 | Dr Colen Kennell | Naval Architect | NSWC Carderock - Code 242 |
| 2 | Mr Mark Selfridge | Naval Architect | UK MoD Exchange Officer |
| 3 | Mr Michael Gilbertson | Naval Architect | UK MoD Graduate |
| 4 | Mr Paul Hawkins | Software Engineer | UK MoD Graduate |
| 5 | Ms Amber Huffman | Mechanical Engineer | NSWC Carderock - Code 282 |
| 6 | Mr Ryan Hayleck | Mechanical Engineer | NSWC Carderock - Code 282 |
| 7 | Mr Gary Hall | Modelling & Simulation | NSWC Carderock - Code 282 |
| 8 | Mr Jon Wrinn | Marine Engineer | NSWC Carderock - Code 243 |
| 9 | Mr Peri Perkins | Mechanical Engineer | NSWC Carderock - Code 243 |
| 10 | Mr John Jacobsen | Mechanical Engineer | NSWC Carderock - Code 270 |

# Annex C - Initial Work Specification

20.1.3 RAdm Mal MacKinnon (retired) met with members of the Innovation Cell on 23 January 2003. From that initial meeting the following work specification was provided, representing the sponsors requirements.

## Sea Basing Innovation Cell

## Scope of Work

1. Functional Analysis and Definition – Research into following areas:
   a. operational requirements, OpNav, USMC, Joint, etc.
   b. ocean shipping in general
   c. current and future concepts for logistical support of deployed forces
   d. past efforts re. Sea Basing, i.e., MOBS
   e. areas employing technologies, techniques, equipment, etc., currently in use or planned, that is pertinent to Sea Basing, i.e. off shore oil production, practices in the various shipping trades, e.g., containers, bulk cargo, petroleum products. This will involve literature searches, interviews and/or correspondence with experienced individuals, and all other relevant sources. The results of this research will enable a definition of "Sea Basing", what it is and what it isn't, and confirm that the key and controlling characteristic of "Sea Basing" is seakeeping, control of the motions of bodies of differing sizes.

2. System Synthesis -- Development of a range of system concepts employing ship design practices. This will identify the areas that require further research, study and analysis.

3. Required Technology Road Map -- Identification of technologies needed to fully exploit the system concepts and how they must be matured and then integrated into a total (ship) system design.

## Schedule/Deliverables

Phase 1 above will take approximately 6-8 weeks. Depending on what the research and analysis shows, a schedule for completion of phases 3 and 4 will be developed. The estimated time to complete 3 and 4 will be on the order of 3-4 months.

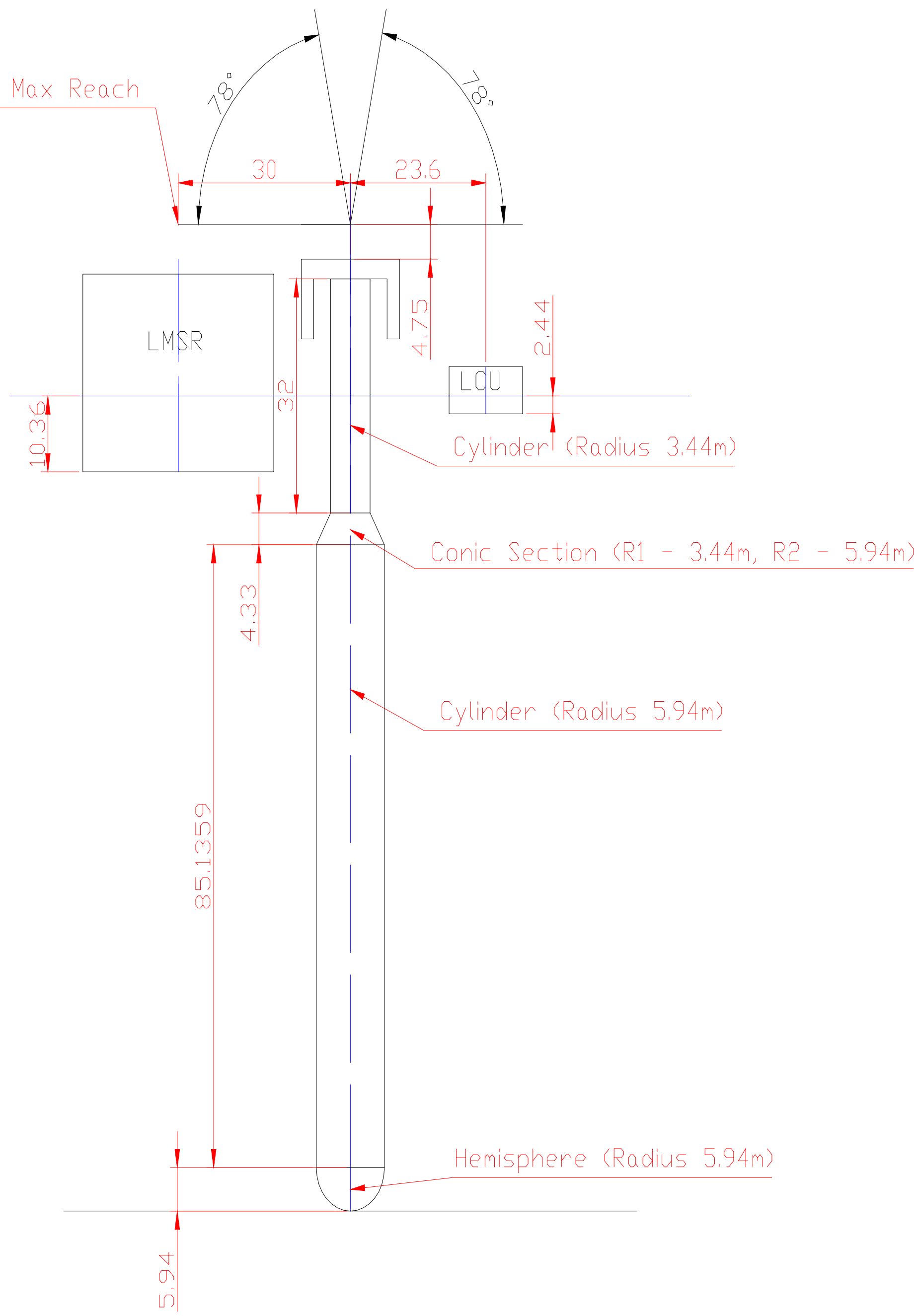
The deliverables will be:

Phase 1 – A concise definition of the tasking submitted for approval to allow subsequent phases to begin and a presentation and written report outlining the results of the research and functional analysis.

Phases 2 and 3 – A comprehensive report of the total project.

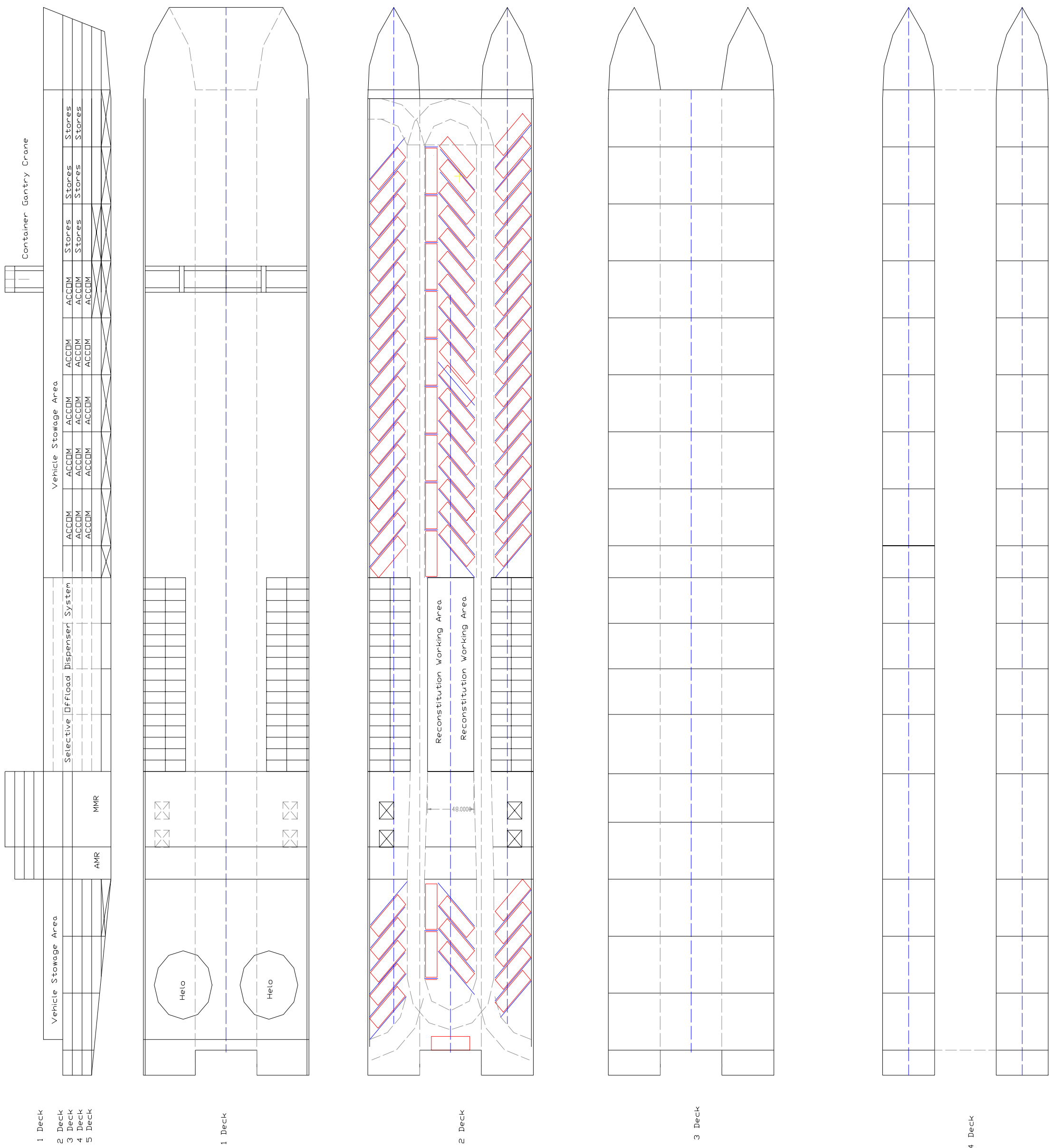
## Annex D - Deep Water Stable Craneship Arrangement

20.1.4 AutoCAD drawing of the Deep Water Stable Craneship;



# Annex E - Seabase Hub General Arrangement

20.1.5 General arrangement of the seabase hub;



## Annex F - Summary of Current Heavy Lift Ships

20.1.6 A tabular summary of current heavy lift float-on / float-off ships;

# ***Heavy Lift Semi-Submersibles***

| Ship | Owner | Deck area (sq.ft) | Deck space w x l (ft) | Length o.a. (ft) | Beam (ft) | Depth (ft) | Max draft (ft) | Feeboard at max draft (ft) | Cargo Capacity (t) | Max. speed (kn) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Open Deck Ships** | | | | | | | | | | |
| Blue Marlin (enlarged) | Dockwise | 120,846 | 206 x 584 | 734.9 | 206.7 | 43.6 | 33.8 | 9.8 | 85,980 | tbd |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mighty Servant I | Dockwise | 80,729 | 164 x 492 | 623.5 | 164 | 39.37 | 28.8 | 10.57 | 44,301 | 15 |  |
| Black Marlin | Dockwise | 80,561 | 137 x 584 | 714.6 | 160.7 | 43.6 | 33.2 | 10.4 | 62,854 | 14.5 |  |
| Mighty Servant III | Dockwise | 60,277 | 131 x 459 | 594.6 | 131.2 | 39.4 | 29.7 | 9.7 | 30,556 | 15 |  |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Transshelf | Dockwise | | 131 x 433 | 567.6 | 131.2 | 39.4 | 28.9 | 10.5 | 37,511 | 15 |
| American Cormorant | NMA | 51,023 | 135 x 378 | 738.4 | 135 | 34.4 | tbd | tbd | 57,421 | 14 |
| Tai An Kou | NMA | 54,103 | 131 x 413 | tbd | 131 | tbd | tbd | tbd | 18,188 | 15 |
| **Barges** | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Giant VI | Semco | | 131 x 369 | 393.7 | 131.2 | 24.6 | 18 | 6.6 | 21,605 | 15 |  | |
| Giant V | Semco | | 101 x 384 | 442.9 | 101.7 | 26.2 | 19.7 | 6.5 | 18,739 | tbd |  | |
| **Open Deck/Dual Cargo** | | | | | | | | | | | **Cargo tank cap. (cu.ft)** | |
| Swan, Tern | Dockwise | 43,130 | 105 x 413 | 592.2 | 105.8 | 43.6 | 32.7 | 10.9 | 35,990 | 15.8 | 1,162,841 |  |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Swift, Teal | Dockwise | 43,130 | 105 x 413 | 593.2 | 105.8 | 43.6 | 32.8 | 10.8 | 35,480 | 15.8 | 1,162,700 |  |

## Annex G - Automated Parking Garages

20.1.7 Team members visited a number of automated parking garages to determine the capabilities of such systems and to provide some initial inspiration for the Seabased Selective Offload concepts. The following text outlines the various concepts and some of the system issues associated with taking such systems to sea.

### Automated Parking Garage Concepts

Automated parking concepts were surveyed to investigate their use for selective offload of vehicles on ships. The team visited two automated parking garages designed by two different companies. Automated parking garage technology has potential for use onboard ships, however several issues were identified in taking land based parking systems to sea. The systems were developed by Robotic Parking and SpaceSaver Parking Company.

Robotic Parking is a manufacturer of robotic parking systems for parking garages. Currently, they have an operational public garage in Hoboken, New Jersey.
The Robotic Parking system is a pallet handling system designed for automobiles. By implementing a robotic parking system in a parking garage, the space can accommodate twice as many vehicles due to the fact that ramps and overhead space are not needed since machinery is moving the vehicles. In addition, there is the possibility of having service bays for oil changes or even a car wash controlled and queued by Robotic Parking's proprietary control system. Robotic parking systems are modular and can be removed or rearranged and can be configured in a stepped formation to accommodate the shape of a ship's hull. In addition, the system was designed for reliability and has redundancy built into the system to minimize down time. The computer controls the throughput and the logic behind the parking system. The Robotic Parking system can park vehicles up to three rows deep serviced by one pallet carrier lane, however, for optimal throughput two are recommended.

The method for parking a vehicle begins by driving the vehicle onto a pallet in the entrance bay. Sensors and displays provide feedback to the driver if the car is properly positioned on the pallet. The drive exits the vehicle and scans their parking card informing the control system to move the pallet. The control system records the driver's information and instructs a pallet carrier on the entrance level to remove the pallet. Once the pallet is secured on the pallet carrier, the pallet is rotated 180 degrees so that the vehicle is pointing in the right direction when it is later removed. The pallet carrier moves and transfers the pallet to a vertical lift that raises the pallet to the level determined by the control system. A pallet carrier serving that level removes the pallet from the lift and transfers it to the vehicles designated parking space. During the stowage of the vehicle, an empty pallet is moved from a pallet buffer to the entrance bay for the next vehicle. To remove the vehicle, the driver scans the identification card and the control system delivers the vehicle to an exit bay.

Figure 1: View of Pallet Carrier and vehicles stowed on rack. Robotic Parking, Hoboken NJ

Figure 2: Vehicle on Pallet Carrier. Note: Two pallet carriers serve each level. Robotic Parking, Hoboken, NJ.

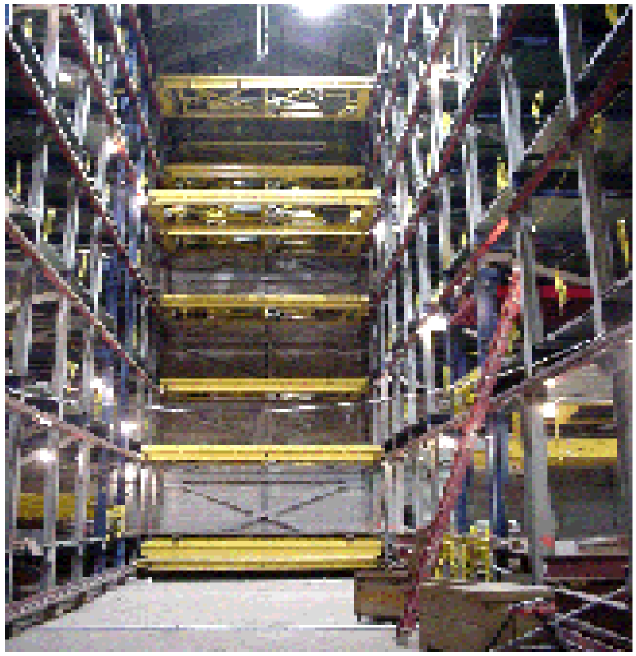


Figure 3: Elevation View of Robotic Parking Hoboken, NJ Garage

SpaceSaver Parking Company manufactures a variety of space saving parking technologies such as an automated parking garage system. The SpaceSaver automated garage is based on warehouse technology. SpaceSaver automated garage systems can accommodate two to three times as many vehicles. The automated garage systems are modular and can be configured the same as Robotic Parking's system. The system is control by a computer and has the capability to use manual controls as used in elevators. The SpaceSaver system can park vehicles up to three rows deep serviced by one storage and retrieval unit lane. According to SpaceSaver, a system with one lift lane and two rows of vehicle on each side and two entry/exit rooms would utilized about 80% of the volume for parking vehicles. In addition, having 2 entry/exit rooms would yield a throughput of about 60 vehicles per hour.

The method for parking a vehicle begins by driving the vehicle onto a pallet in the entrance room. Sensors and displays provide feedback to the driver if the car is properly positioned on the pallet. The drive exits the vehicle and scans their parking card informing the control system to move the pallet. The control system records the driver's information, rotates the pallet 15 degrees so that it is inline with a vertical lift. This is due to the fact that the entrance is at an angle to garage system. The pallet is lowered into the garage since the garage is beneath the building. A storage and retrieval unit raises and lowers as it moves along the lane. The storage and retrieval unit removes the pallet and at the same time replaces it with an empty one for the next vehicle. The vertical lift raises the empty pallet to the entrance room for the next vehicle. The storage and retrieval then moves the pallet to its designated space in the garage. To remove the vehicle, the driver scans the identification card and the control system delivers the vehicle to the exit room where it rotates the vehicle so it is pointed in the right direction.

SpaceSaver is currently working with the offshore oil industry to adapt their elevator technology for lifting small boats out of the water for maintenance.

Automated parking systems are modular and can be configured to most spaces. They provide fast load and offload times and reduce the need for driving lanes, ramps, lighting and ventilation. The systems also can operate using generators in case of ship power failure. The systems can be designed to accommodate different vehicle sizes. Automated parking systems provide high stowage factors and provide for selective offload capability.

The automated parking concepts would require the capability of lashing the vehicles to the pallets and the ability to secure the pallets to the rack when stored. According to the manufacturers, a pallet locking mechanism is a feasible modification to the automated parking systems. Lashing the vehicles to the pallets would reduce throughput, therefore, a quick lashing system or lashing staging area could improve throughput. Additionally, both systems use counter weights to assist the lifting of the vehicles and would require analysis determining the impact of ship motions on counter weight systems.

Both systems use off the shelf components and are designed for vehicles up to 5,000lbs. An automated system for use with military vehicles, such as M998 HMMWVs, would require customized components along with the other modifications for making the system military worthy.

Figure 4: Vehicle on Storage and Retrieval Unit. SpaceSaver Parking, Washington

Figure 5: Vehicle on Storage and Retrieval Unit about to exchange space with empty pallet. SpaceSaver Parking, Washington, D.C.

**Park Plus**

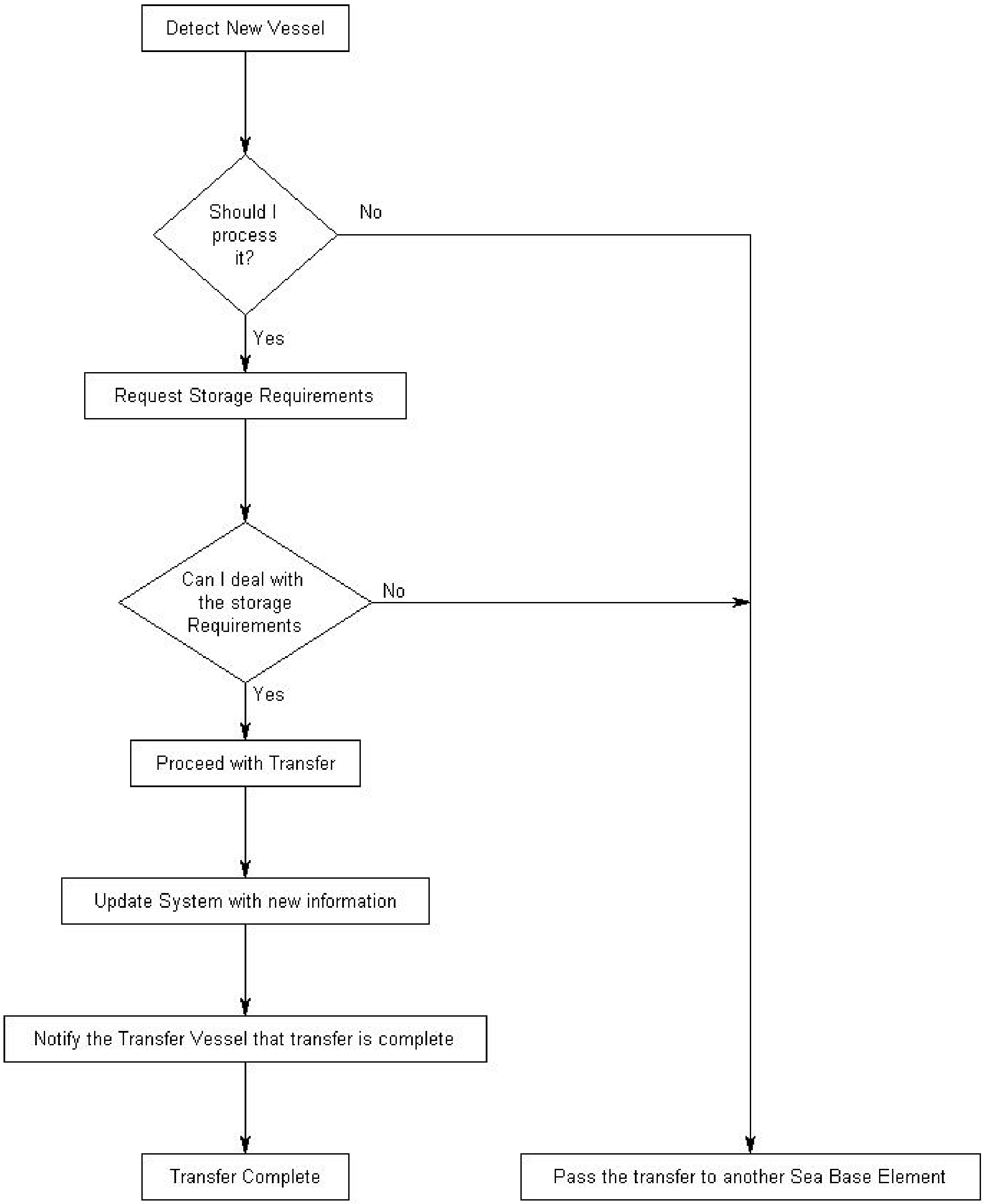
Park Plus, as well as SpaceSaver Parking, manufacture a vehicle lift that allows for stowage of one vehicle under another. This system would prove useful where ship space could accommodate two vehicles in height. The system shown in the pictures below was manufactured by Park Plus and installed at a Mercedes dealership in Arlington, Virginia.

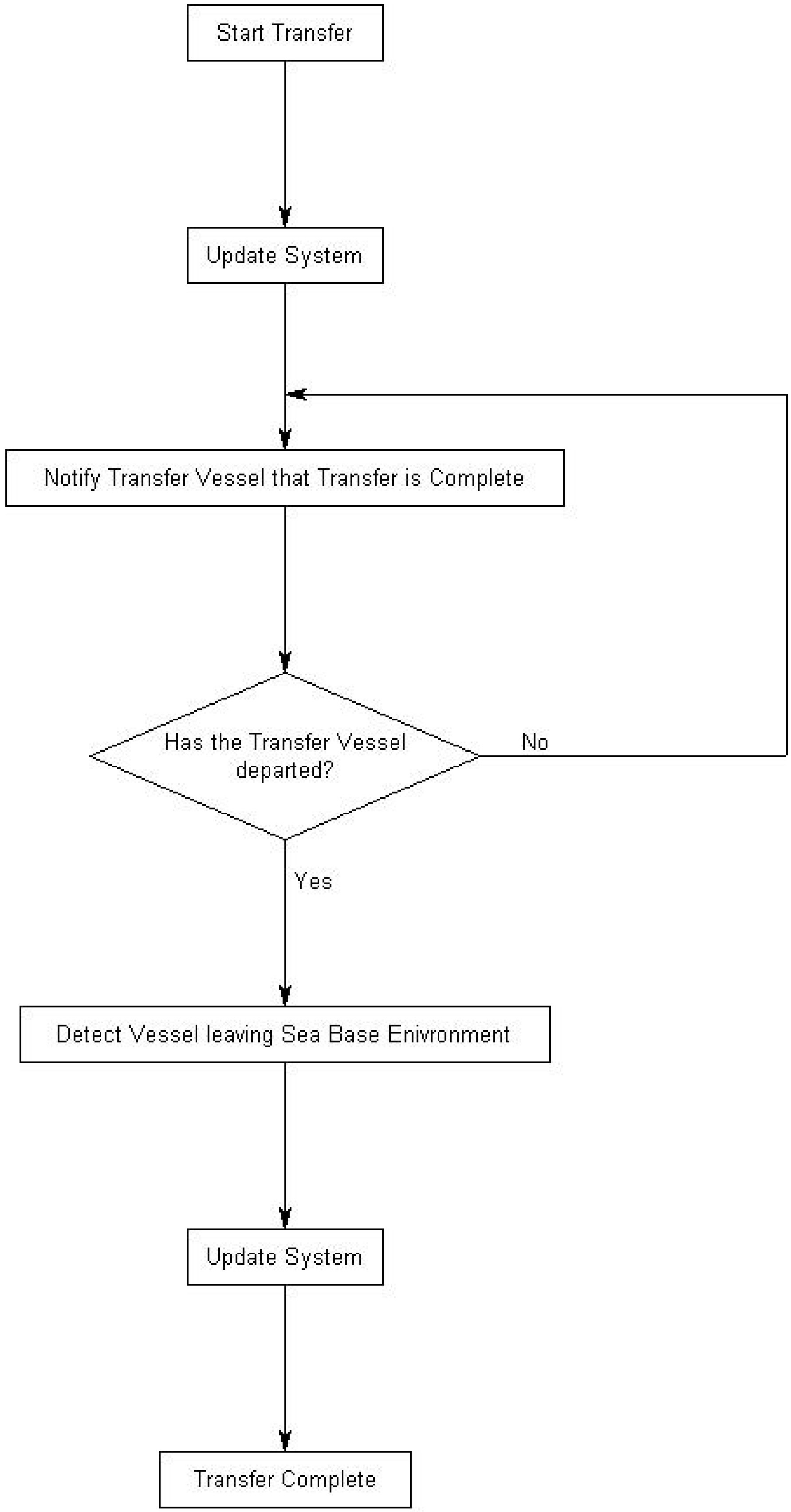

Figure 6:  Park Plus Vehicle Lift

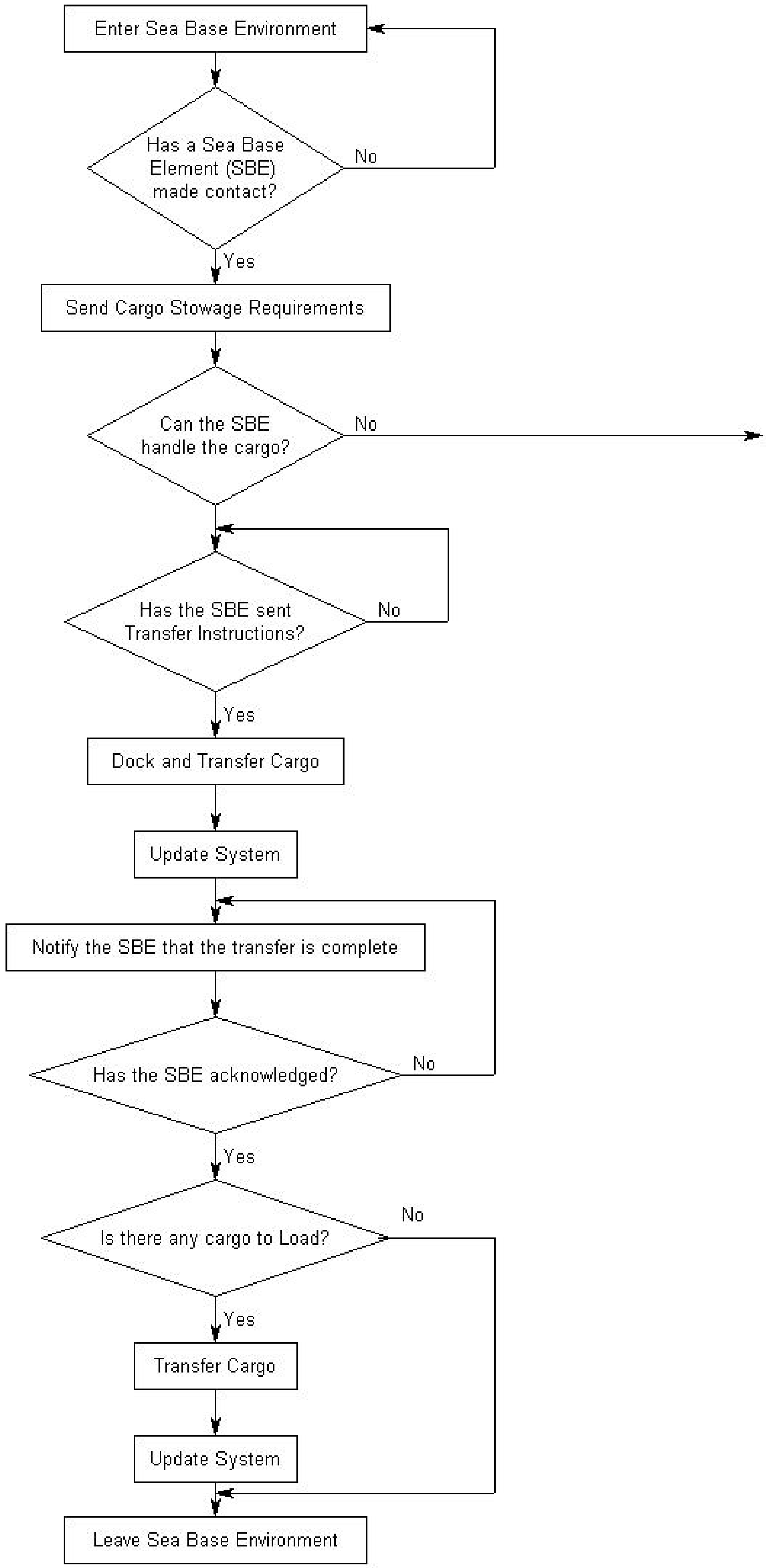
Figure 7:  Park Plus Vehicle Lift

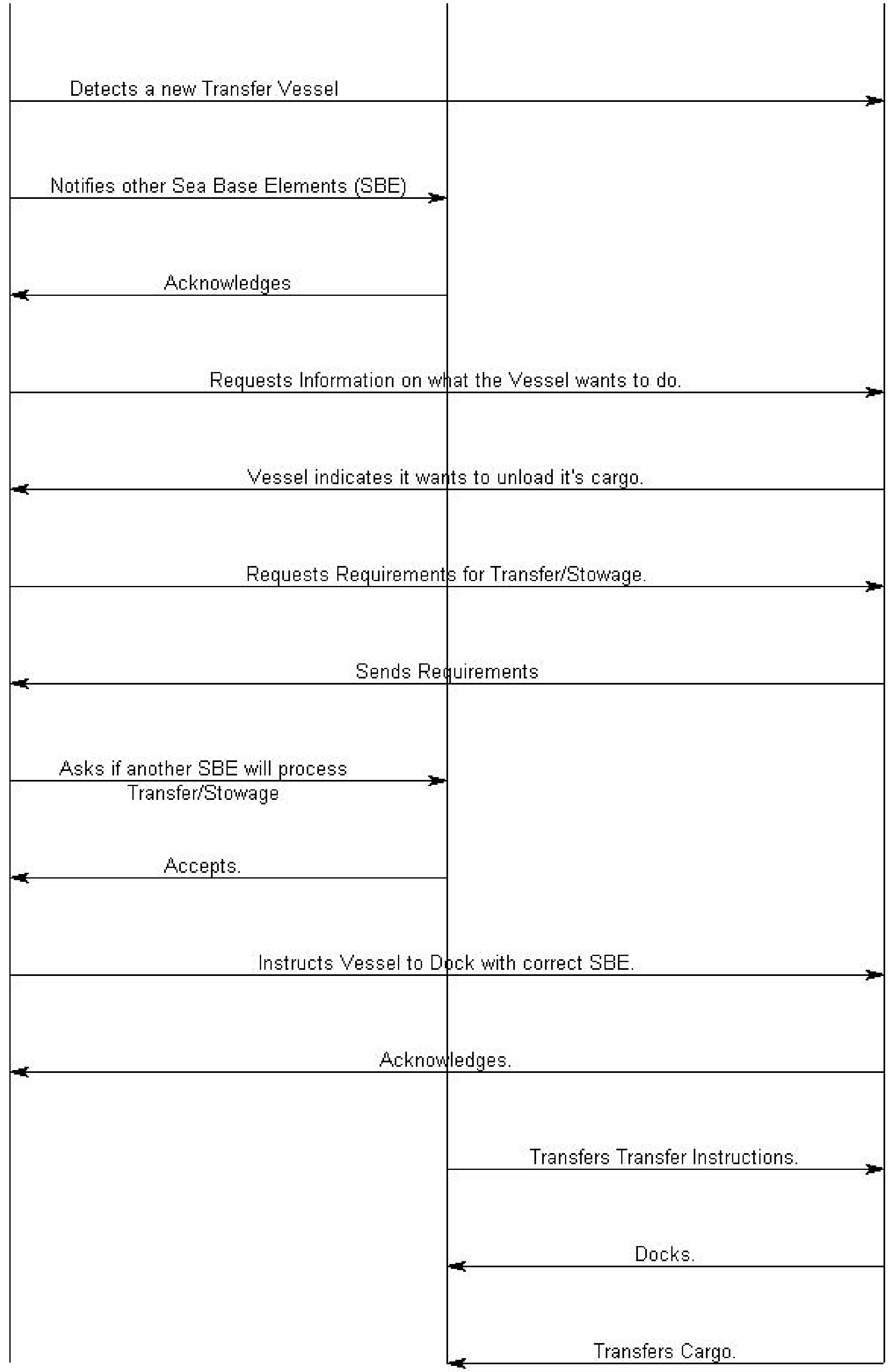
## Annex H - Management System Flowchart

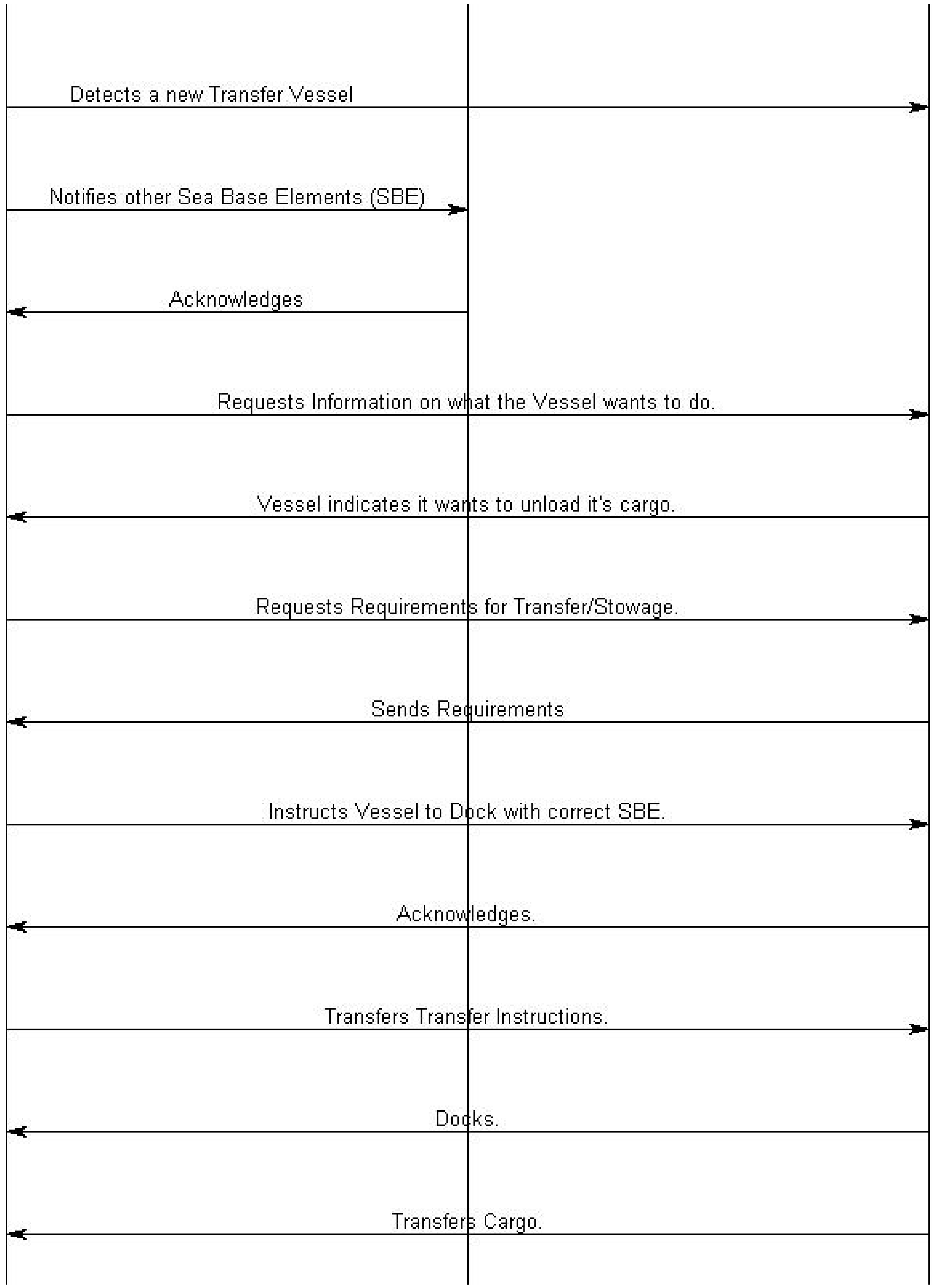
20.1.8 Management system flowchart.




Start Transfer
Update System
Notify Transfer Vessel that Transfer is Complete
Has the Transfer Vessel departed?
No
Yes
Detect Vessel leaving Sea Base Enivronment
Update System
Transfer Complete


Enter Sea Base Environment
Has a Sea Base Element (SBE) made contact?
No
Yes
Send Cargo Stowage Requirements
Can the SBE handle the cargo?
No
Has the SBE sent Transfer Instructions?
No
Yes
Dock and Transfer Cargo
Update System
Notify the SBE that the transfer is complete
Has the SBE acknowledged?
No
Yes
Is there any cargo to Load?
No
Yes
Transfer Cargo
Update System
Leave Sea Base Environment


Detects a new Transfer Vessel
Notifies other Sea Base Elements (SBE)
Acknowledges
Requests Information on what the Vessel wants to do.
Vessel indicates it wants to unload it's cargo.
Requests Requirements for Transfer/Stowage.
Sends Requirements
Asks if another SBE will process Transfer/Stowage
Accepts.
Instructs Vessel to Dock with correct SBE.
Acknowledges.
Transfers Transfer Instructions.
Docks.
Transfers Cargo.


Detects a new Transfer Vessel
Notifies other Sea Base Elements (SBE)
Acknowledges
Requests Information on what the Vessel wants to do.
Vessel indicates it wants to unload it's cargo.
Requests Requirements for Transfer/Stowage.
Sends Requirements
Instructs Vessel to Dock with correct SBE.
Acknowledges.
Transfers Transfer Instructions.
Docks.
Transfers Cargo.

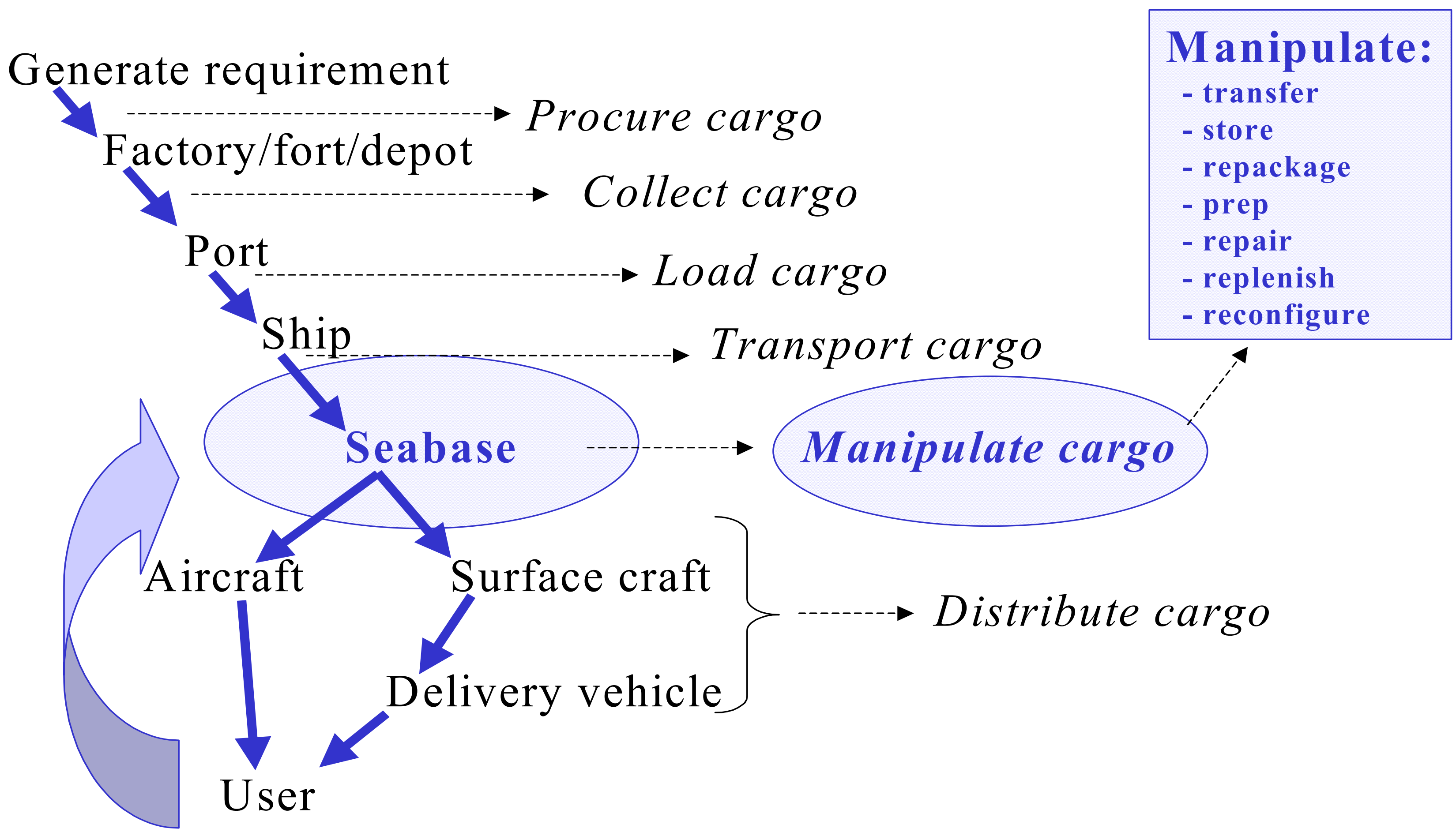
| | | |
|---|---|---|
| | Manage Sea Base | |
| 1 | Manage Equipment | |
| 1.1 | Add New Equipment | |
| 1.1.1 | | Add Equipment, enter properties into system |
| 1.1.2 | | Add Equipment availability requirements |
| 1.2 | Track Equipment | |
| 1.2.1 | | Identify when equipment enters the sea base |
| 1.2.1.1 | | Identify new supply vessel |
| 1.2.1.2 | | Identify equipment |
| 1.2.1.3 | | Update System |
| 1.2.2 | | Track Location |
| 1.2.2.1 | | Track Unloading |
| 1.2.2.1.1 | | Identify Unloading |
| 1.2.2.1.2 | | Update System |
| 1.2.2.2 | | Track Transfer |
| 1.2.2.2.1 | | Update System |
| 1.2.2.3 | | Track Loading |
| 1.2.2.3.1 | | Identify loading |
| 1.2.2.3.2 | | Update System |
| 1.2.3 | | Identify when equipment leaves the sea base |
| 1.2.3.1 | | Identify Equipment |
| 1.2.3.2 | | Identify Transport |
| 1.2.3.3 | | Update System |
| 1.3 | Delete Equipment | |
| 2 | Manage Spaces | |
| 2.1 | Add new space | |
| 2.1.1 | | Identify Vessel |
| 2.1.2 | | Query Vessel to get information |
| 2.1.3 | | Update System |
| 2.2 | Allocate Space | |
| 2.2.1 | | Identify Transfer Requirements |
| 2.2.1.1 | | Identify Equipment |
| 2.2.1.1.1 | | Identify Incoming vessel |
| 2.2.1.1.2 | | Get Requirements |
| 2.2.1.2 | | Calculate Complete Requirements |
| 2.2.2 | | Find Appropriate Space |
| 2.2.3 | | Allocate and Update System |
| 2.3 | Delete Space | |
| 2.3.1 | | Identify Space |
| 2.3.2 | | Update System |

## Management System Requirements

| RA No | Requirement | | Associated FA |
|---|---|---|---|
| *A. Manage Equipment* | | | |
| A1 | The system must be able to manage the equipment information that will be used within the system | Required | 1 |
| A2 | The system must be able to accept new equipment information | Required | 1.1 |
| A3 | The system must be able to accept the physical properties of a system | Required | 1.1.1 |
| A4 | The system must be able to accept the availability information of a piece of equipment | Required | 1.1.2 |
| A5 | The system must allow the deletion of equipment information | Required | 1.3 |
| A6 | The system must be able to track equipment through the sea base | Required | 1.2 |
| A7 | It must be possible to manually notify the system that a piece of equipment has entered the sea base environment | Required | 1.2.1 |
| A8 | The system must be able to automatically track a piece of equipment while it is within the sea base environment | Optional | 1.2.1 |
| A9 | It must be possible to manually notify the system that a transport vehicle/vessel has entered the sea base environment | Required | 1.2.1.1 |
| A10 | The system must be able to automatically identify when a transport vehicle/vessel enters the sea base environment | Optional | 1.2.1.1 |
| A11 | It must be possible to manually notify the system what equipment is present on a transport vehicle/vessel | Required | 1.2.1.2 |
| A12 | The system must be able to automatically identify what equipment is present on a transport vehicle/vessel | Optional | 1.2.1.2 |
| A13 | It must be possible to manually notify the system that an equipment transfer has taken place and provide the new location information | Required | 1.2.2.2 |
| A14 | The system must be able to automatically identify that an equipment transfer has taken place and detect the new location information | Optional | 1.2.2.2 |
| A15 | It must be possible to manually notify the system that a transport vehicle/vessel has left the sea base environment | Required | 1.2.3 |
| A16 | The system must be able to automatically identify that a transport vehicle/vessel has left the sea base environment | Optional | 1.2.3 |
| A17 | The system must be able to automatically update the equipment information stored for any piece of equipment that is located on a transport vehicle/vessel that has left the sea base environment | Optional | 1.2.3 |
| *B. Manage Spaces* | | | |
| B1 | The system must be able to manage the available reconfigarable spaces within the sea base environment | Required | 2 |
| B2 | The system must be able to create new reconfigurable space records | Required | 2.1 |
| B3 | The system must be able to identify the transport vehicle/vessel to which the reconfigurable space belongs | Required | 2.1.1 |
| B4 | The system must be able to obtain the reconfigurable space information automatically from the transport vehicle/vessel | Required | 2.1.2 |
| B5 | The system must be able to allocate a reconfigurable space when one is requested to perform a function. | Required | 2.2 |
| B6 | The system must be able to allocate a reconfigurable space that minimizes lost space. | Required | 2.2 |
| B7 | The system must be able to identify the requirements to perform a function in order to allocate a reconfigurable space. | Required | 2.2.1 |
| B8 | The system must be capable of accepting manual information with regard to the equipment to be used in the reconfigurable space to be assigned | Required | 2.2.1.1 |
| B9 | The system must be able to identify the required equipment information, for the equipment involved in the required function, automatically. | Required | 2.2.1.1 |
| B10 | The system must be able to delete a reconfigurable space when requested | Required | 2.3 |
| B11 | The system must be able to automatically delete a reconfigurable space when the vessel leaves the sea base environment | Optional | 2.3 |

**Annex I - Seabasing Functional Analysis**

20.1.9 The diagram below depicts the individual 'steps' in the seabasing logistics chain;



## Annex J - Spiral Ramps : 3D Solid Models

20.1.10 3D solid models for the spiral ramp concepts;

**FIGURE 1. A 3D SOLID MODEL SHOWING ONE SPIRAL**

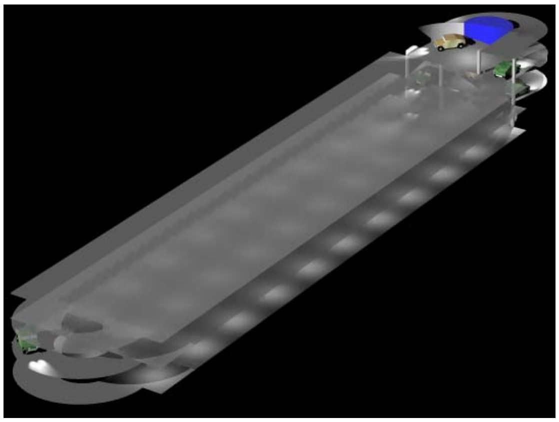
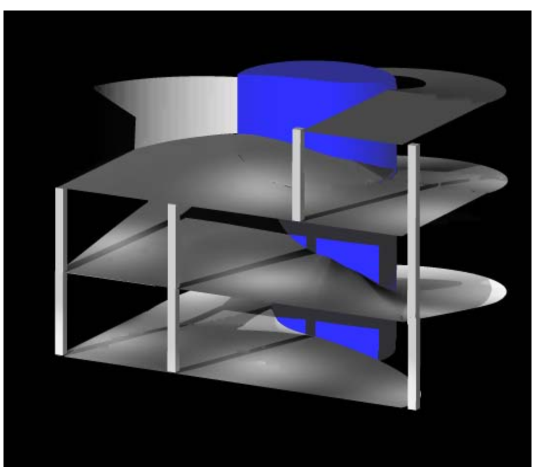


Figure 2. A 3D Solid Models showing one spiral (Brown up, Green down)



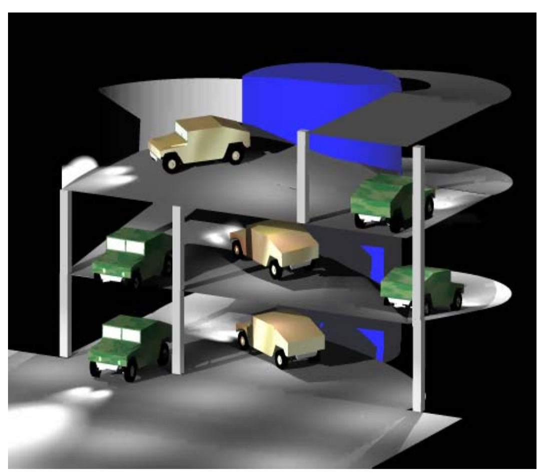


Figure 3. A 3D Solid Model showing two spirals

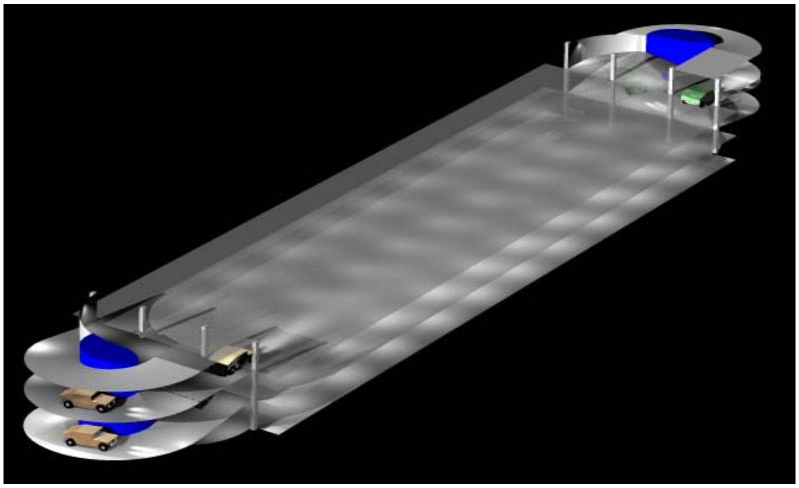
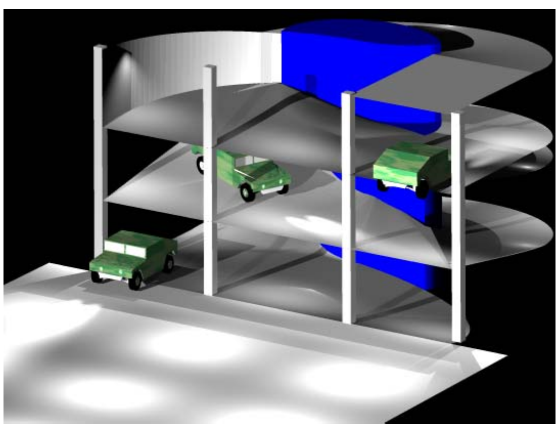


Figure 4. A 3D Solid Model showing two spirals (green down, brown up)



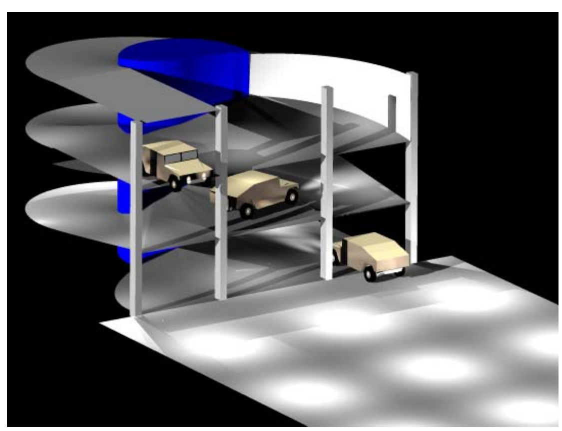


Figure 5. A 3D Solid Model showing half spirals

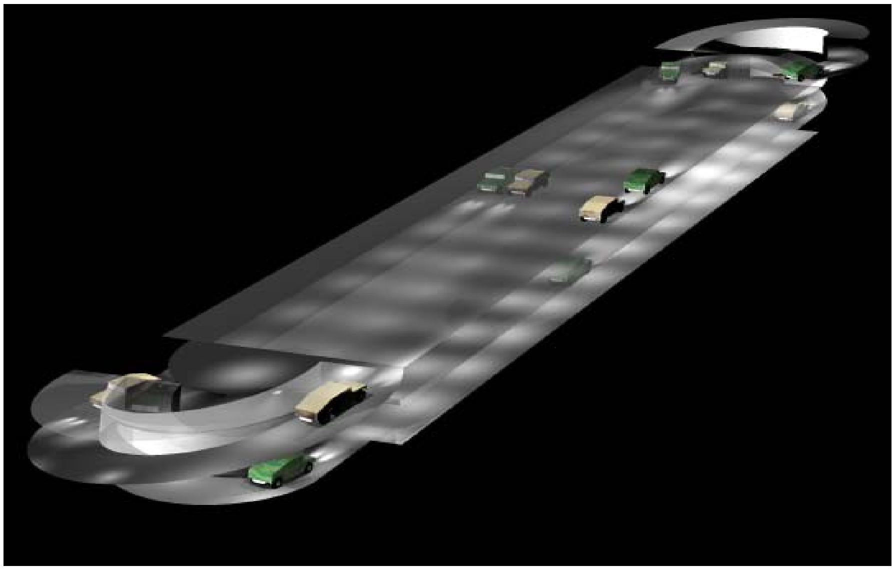
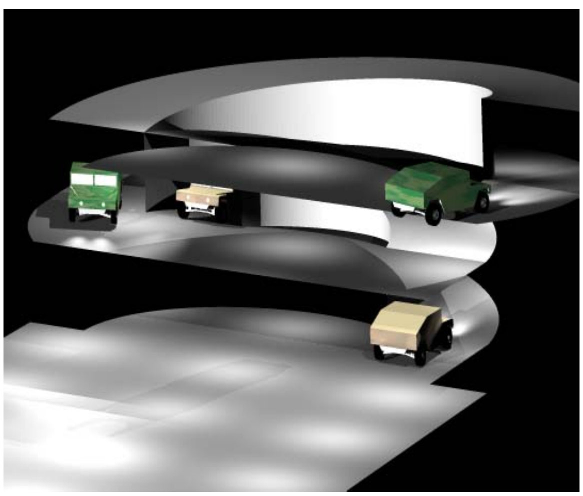
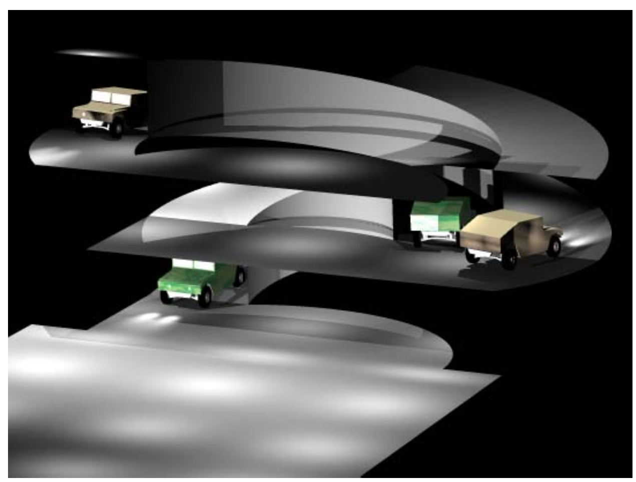


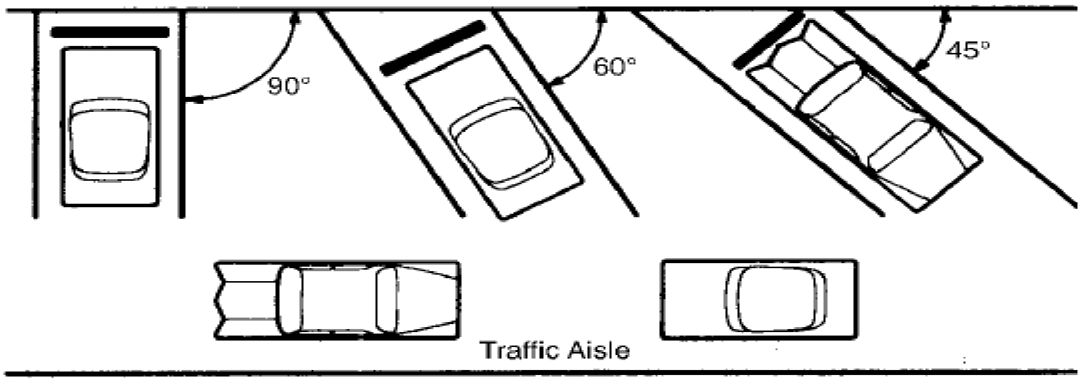
Figure 6. A 3D Solid Model showing half spirals (green down, brown up)

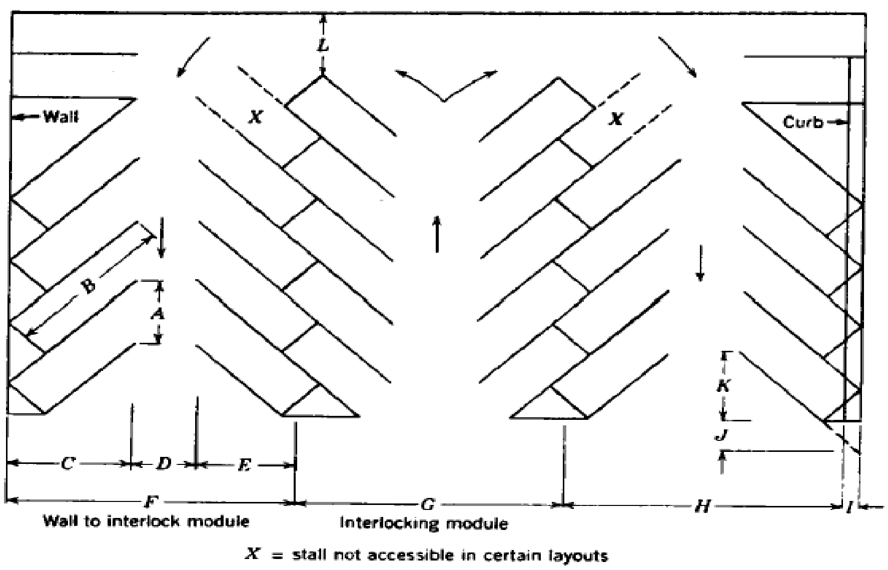




## Annex K - Tabular Summaries & Plots of Stowage Factor

20.1.11 This Annex provides details of parking arrangements, stowage factor calculations and plots for the various cargo arrangements that were developed.



**STALL LAYOUT ELEMENTS**

| Dimension | On diagram | 45° | 60° | 75° | 90° |
|---|---|---|---|---|---|
| Stall width parallel to aisle | A | 12.7 | 10.4 | 9.3 | 9.0 |
| Stall length of line | B | 25.0 | 22.0 | 20.0 | 18.5 |
| Stall depth to wall | C | 17.5 | 19.0 | 19.5 | 18.5 |
| Aisle width between stall lines | D | 12.0 | 16.0 | 23.0 | 26.0 |
| Stall depth, interlock | E | 15.3 | 17.5 | 18.8 | 18.5 |
| Module, wall to interlock | F | 44.8 | 52.5 | 61.3 | 63.0 |
| Module, interlocking | G | 42.6 | 51.0 | 61.0 | 63.0 |
| Module, interlock to curb face | H | 42.8 | 50.2 | 58.8 | 60.5 |
| Bumper overhang (typical) | I | 2.0 | 2.3 | 2.5 | 2.5 |
| Offset | J | 6.3 | 2.7 | 0.5 | 0.0 |
| Setback | K | 11.0 | 8.3 | 5.0 | 0.0 |
| Cross aisle, one-way | L | 14.0 | 14.0 | 14.0 | 14.0 |
| Cross aisle, two-way | M | 24.0 | 24.0 | 24.0 | 24.0 |

Alternative Cargo Arrangements for 100% Selective Offload

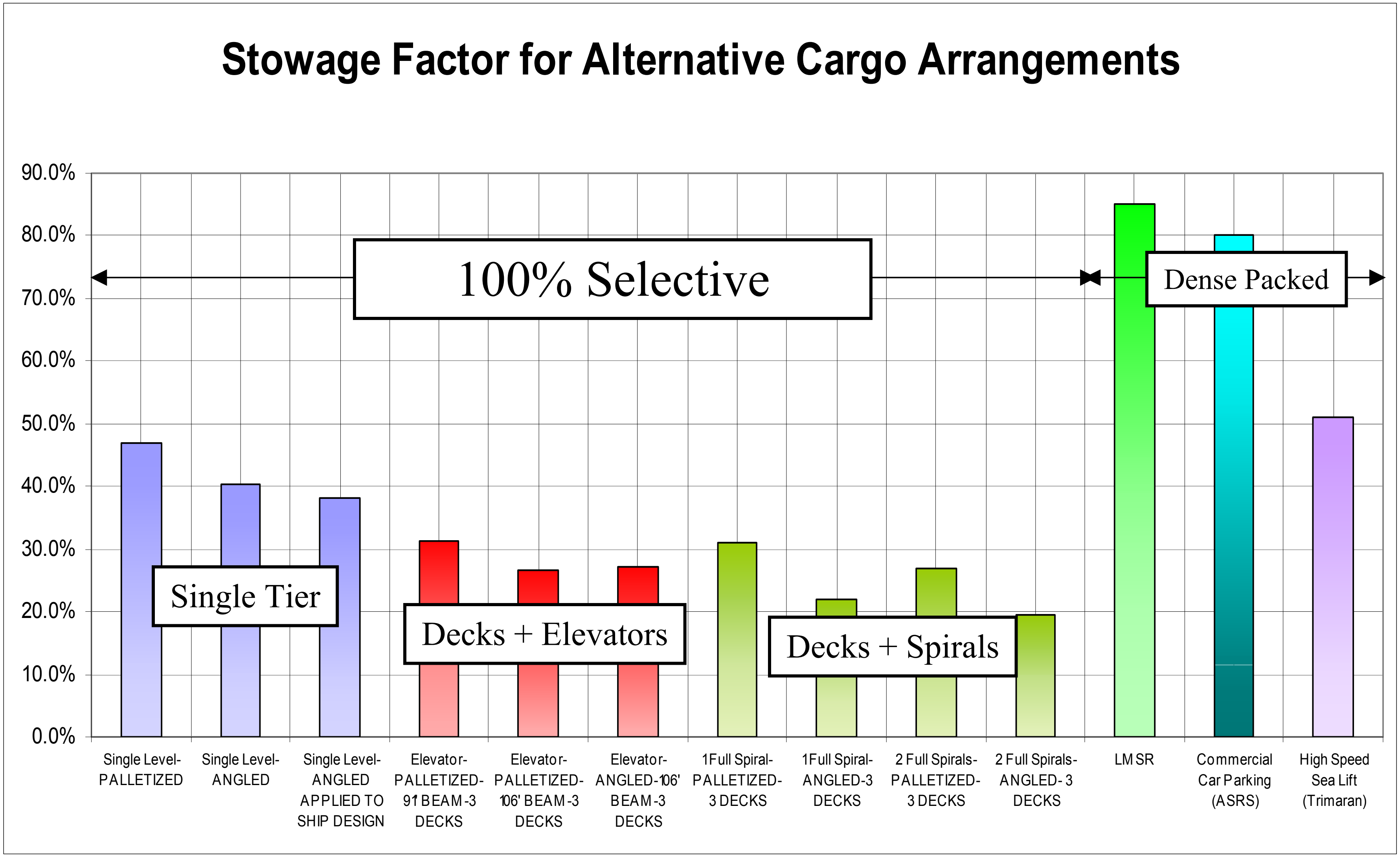
| ARRANGEMENT DISCRIPTION | BEAM | CARGO DECK LENGTH | TOTAL LENGTH | NUMBER OF VEHICLES | VEHICLE AREA | CARGO AREA | DECK AREA | SPIRAL RAMP AREA | TOTAL AREA | STOWAGE FACTOR | AVERAGE STOWAGE FACTOR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Single Level- PALLETIZED** | 172 ft | 414 ft | 519 ft | 80 | 38,400 ft^2 | 71,208 ft^2 | 10,898 ft^2 | 0 ft^2 | 82,106 ft^2 | 47.0% | ~~~~ |
| **Single Level-ANGLED** | 172 ft | 531 ft | 596 ft | 80 | 38,400 ft^2 | 91,280 ft^2 | 4,344 ft^2 | 0 ft^2 | 95,644 ft^2 | 40.2% | ~~~~ |
| **Single Level- ANGLED: ACTUAL SHIP DESIGN** | 172 ft | 592 ft | 684 ft | 80 | 38,400 ft^2 | 100,478 ft^2 | 0 ft^2 | 0 ft^2 | 100,477 ft^2 | 38.2% | ~~~~ |
| **Elevator- PALLETIZED-91' BEAM-3 DECKS** | 91 ft | 455 ft | 554 ft | 84 | 40,320 ft^2 | 124,215 ft^2 | 5,874 ft^2 | 0 ft^2 | 130,089 ft^2 | ~~~~ | 31.3% |
| **Elevator- PALLETIZED-91' BEAM-DECK 1** | 91 ft | 455 ft | 554 ft | 28 | 13,440 ft^2 | 41,405 ft^2 | 5,874 ft^2 | 0 ft^2 | 47,279 ft^2 | 28.4% | ~~~~ |
| **Elevator- PALLETIZED-91' BEAM-DECK 2** | 91 ft | 455 ft | 554 ft | 28 | 13,440 ft^2 | 41,405 ft^2 | 0 ft^2 | 0 ft^2 | 41,405 ft^2 | 32.5% | ~~~~ |
| **Elevator- PALLETIZED-91' BEAM-DECK 3** | 91 ft | 455 ft | 554 ft | 28 | 13,440 ft^2 | 41,405 ft^2 | 0 ft^2 | 0 ft^2 | 41,405 ft^2 | 32.5% | ~~~~ |
| **Elevator- ANGLED-91' BEAM-3 DECKS** | Angled Parking Is Not Possible With A 91' Beam- Turning Radius for Vehicles Requires A Larger Beam. | | | | | | | | | | |
| **Elevator- PALLETIZED-106' BEAM-3 DECKS** | 106 ft | 455 ft | 554 ft | 84 | 40,320 ft^2 | 144,690 ft^2 | 6,580 ft^2 | 0 ft^2 | 151,270 ft^2 | ~~~~ | 26.7% |
| **Elevator- PALLETIZED-106' BEAM-DECK 1** | 106 ft | 455 ft | 554 ft | 28 | 13,440 ft^2 | 48,230 ft^2 | 6,580 ft^2 | 0 ft^2 | 54,810 ft^2 | 24.5% | |
| **Elevator- PALLETIZED-106' BEAM-DECK 2** | 106 ft | 455 ft | 554 ft | 28 | 13,440 ft^2 | 48,230 ft^2 | 0 ft^2 | 0 ft^2 | 48,230 ft^2 | 27.9% | |
| **Elevator- PALLETIZED-106' BEAM-DECK 3** | 106 ft | 455 ft | 554 ft | 28 | 13,440 ft^2 | 48,230 ft^2 | 0 ft^2 | 0 ft^2 | 48,230 ft^2 | 27.9% | |
| **Elevator- ANGLED-106' BEAM-3 DECKS** | 106 ft | 446 ft | 523 ft | 84 | 40,320 ft^2 | 141,828 ft^2 | 6,168 ft^2 | 0 ft^2 | 147,996 ft^2 | ~~~~ | 27.3% |
| **Elevator- ANGLED-106' BEAM-DECK 1** | 106 ft | 446 ft | 523 ft | 28 | 13,440 ft^2 | 47,276 ft^2 | 6,168 ft^2 | 0 ft^2 | 53,444 ft^2 | 25.2% | ~~~~ |
| **Elevator- ANGLED-106' BEAM-DECK 2** | 106 ft | 446 ft | 523 ft | 28 | 13,440 ft^2 | 47,276 ft^2 | 0 ft^2 | 0 ft^2 | 47,276 ft^2 | 28.4% | ~~~~ |
| **Elevator- ANGLED-106' BEAM-DECK 3** | 106 ft | 446 ft | 523 ft | 28 | 13,440 ft^2 | 47,276 ft^2 | 0 ft^2 | 0 ft^2 | 47,276 ft^2 | 28.4% | ~~~~ |
| **1 Full Spiral-PALLETIZED-3 DECKS** | 106 ft | 332 ft | 449 ft | 84 | 40,320 ft^2 | 105,576 ft^2 | 8,088 ft^2 | 16,188 ft^2 | 129,852 ft^2 | ~~~~ | 31.1% |
| **1 Full Spiral-PALLETIZED-DECK 1** | 106 ft | 332 ft | 449 ft | 28 | 13,440 ft^2 | 35,192 ft^2 | 3,310 ft^2 | 5,396 ft^2 | 43,898 ft^2 | 30.6% | ~~~~ |
| **1 Full Spiral-PALLETIZED-DECK 2** | 106 ft | 332 ft | 449 ft | 28 | 13,440 ft^2 | 35,192 ft^2 | 2,389 ft^2 | 5,396 ft^2 | 42,977 ft^2 | 31.3% | ~~~~ |
| **1 Full Spiral-PALLETIZED-DECK 3** | 106 ft | 332 ft | 449 ft | 28 | 13,440 ft^2 | 35,192 ft^2 | 2,389 ft^2 | 5,396 ft^2 | 42,977 ft^2 | 31.3% | ~~~~ |
| **1 Full Spiral-ANGLED-3 DECKS** | 106 ft | 485 ft | 600 ft | 84 | 40,320 ft^2 | 154,230 ft^2 | 10,356 ft^2 | 19,437 ft^2 | 184,023 ft^2 | ~~~~ | 22.0% |
| **1 Full Spiral-ANGLED-DECK 1** | 106 ft | 485 ft | 600 ft | 28 | 13,440 ft^2 | 51,410 ft^2 | 3,452 ft^2 | 6,479 ft^2 | 61,341 ft^2 | 22.0% | ~~~~ |
| **1 Full Spiral-ANGLED-DECK 2** | 106 ft | 485 ft | 600 ft | 28 | 13,440 ft^2 | 51,410 ft^2 | 2,812 ft^2 | 6,479 ft^2 | 60,701 ft^2 | 22.1% | ~~~~ |
| **1 Full Spiral-ANGLED-DECK 3** | 106 ft | 485 ft | 600 ft | 28 | 13,440 ft^2 | 51,410 ft^2 | 2,812 ft^2 | 6,479 ft^2 | 60,701 ft^2 | 22.1% | ~~~~ |
| **2 Full Spirals- PALLETIZED- 3 DECKS** | 106 ft | 371 ft | 527 ft | 84 | 40,320 ft^2 | 117,978 ft^2 | 0 ft^2 | 32,376 ft^2 | 150,354 ft^2 | ~~~~ | 26.8% |
| **2 Full Spirals- PALLETIZED- DECK 1** | 106 ft | 371 ft | 527 ft | 28 | 13,440 ft^2 | 39,326 ft^2 | 0 ft^2 | 10,792 ft^2 | 50,118 ft^2 | 26.8% | |
| **2 Full Spirals- PALLETIZED- DECK 2** | 106 ft | 371 ft | 527 ft | 28 | 13,440 ft^2 | 39,326 ft^2 | 0 ft^2 | 10,792 ft^2 | 50,118 ft^2 | 26.8% | |
| **2 Full Spirals- PALLETIZED- DECK 3** | 106 ft | 371 ft | 527 ft | 28 | 13,440 ft^2 | 39,326 ft^2 | 0 ft^2 | 10,792 ft^2 | 50,118 ft^2 | 26.8% | |
| **2 Full Spirals- ANGLED- 3 DECKS** | 106 ft | 524 ft | 680 ft | 84 | 40,320 ft^2 | 166,632 ft^2 | 0 ft^2 | 38,874 ft^2 | 205,506 ft^2 | ~~~~ | 19.6% |
| **2 Full Spirals- ANGLED- DECK 1** | 106 ft | 524 ft | 680 ft | 28 | 13,440 ft^2 | 55,544 ft^2 | 0 ft^2 | 12,958 ft^2 | 68,502 ft^2 | 19.6% | ~~~~ |
| **2 Full Spirals- ANGLED- DECK 2** | 106 ft | 524 ft | 680 ft | 28 | 13,440 ft^2 | 55,544 ft^2 | 0 ft^2 | 12,958 ft^2 | 68,502 ft^2 | 19.6% | ~~~~ |
| **2 Full Spirals- ANGLED- DECK 3** | 106 ft | 524 ft | 680 ft | 28 | 13,440 ft^2 | 55,544 ft^2 | 0 ft^2 | 12,958 ft^2 | 68,502 ft^2 | 19.6% | ~~~~ |

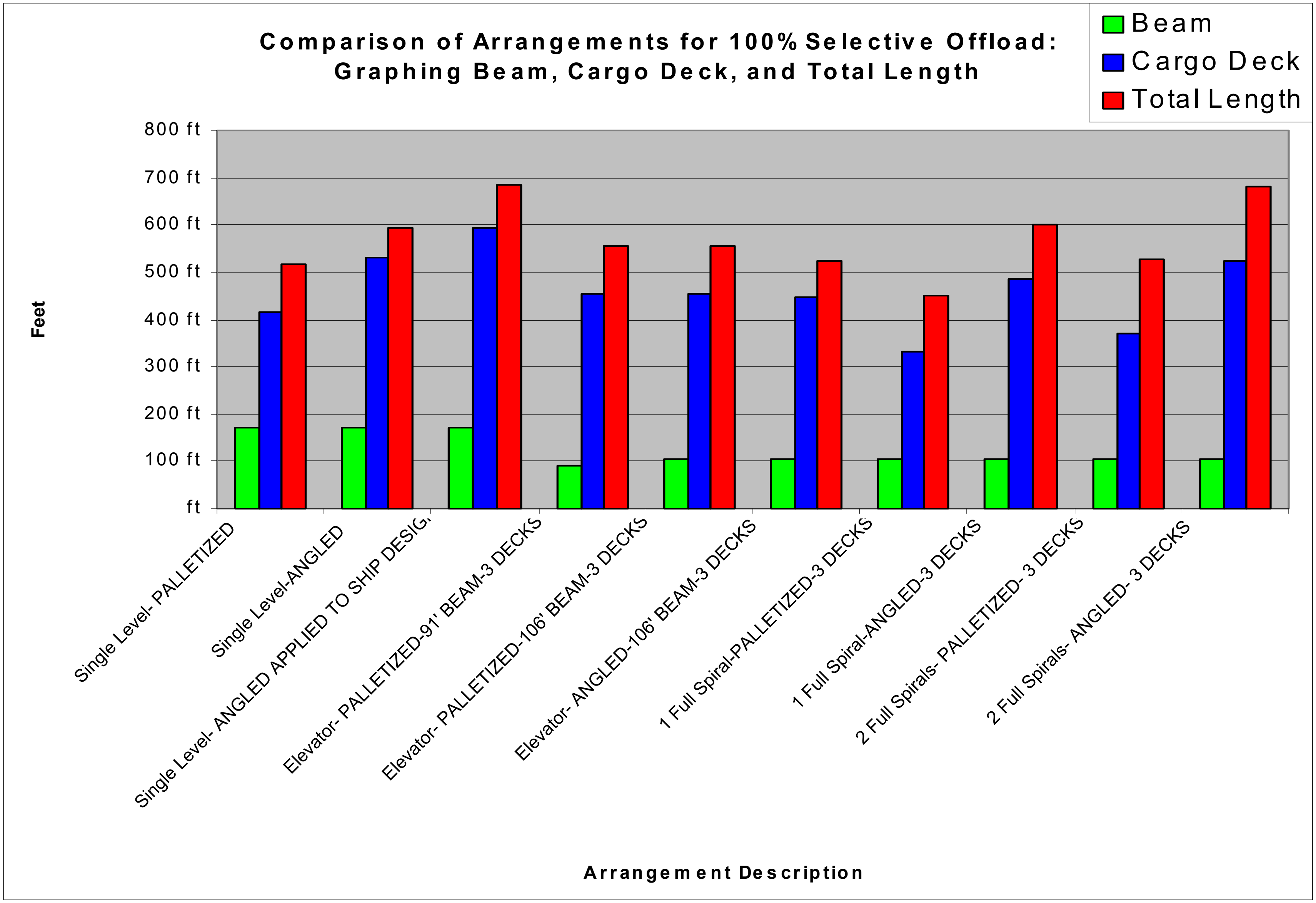
Alternative Cargo Arrangements for 100% Selective Offload

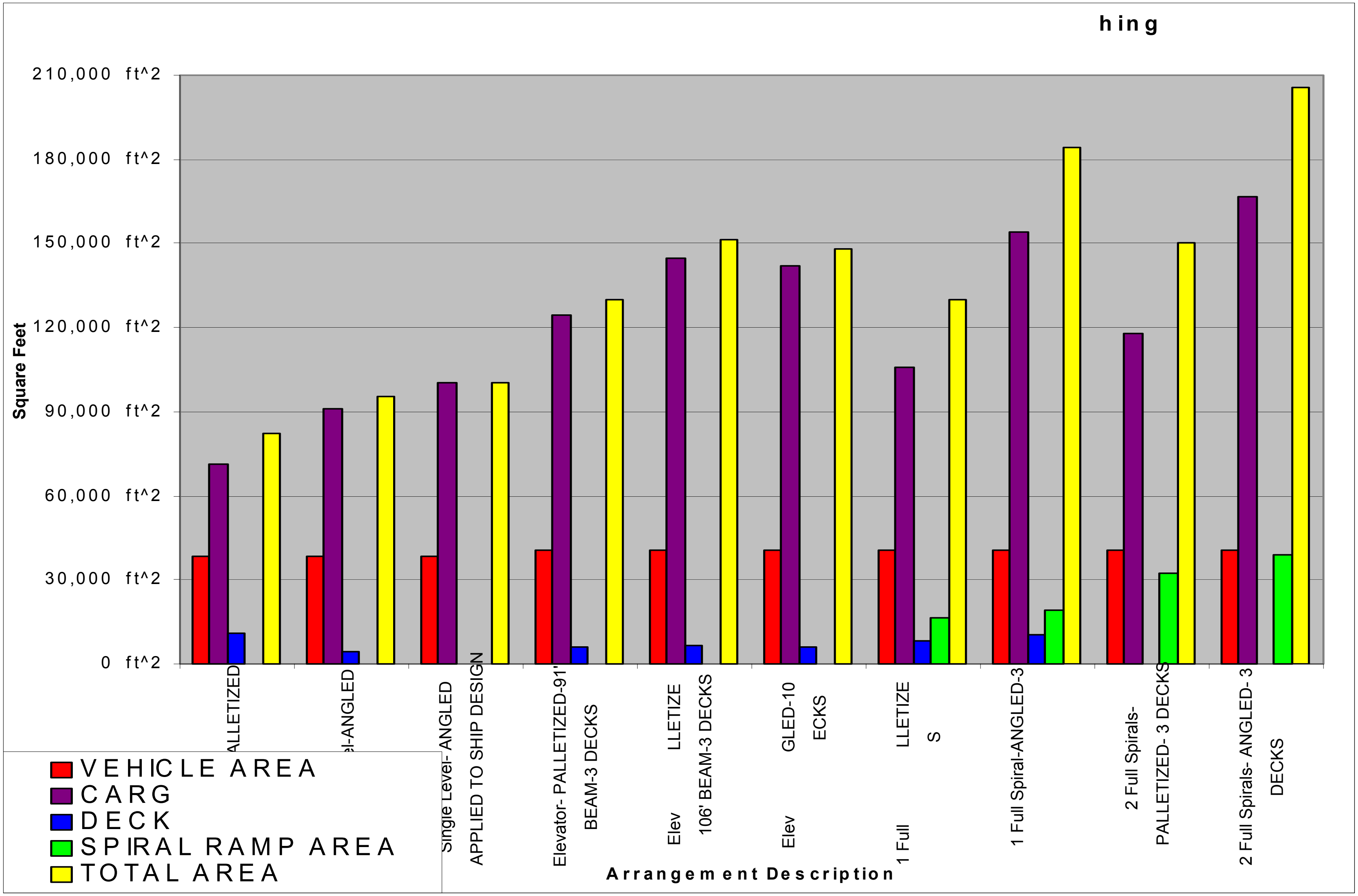
| ARRANGEMENT DISCRIPTION | BEAM | CARGO DECK LENGTH | TOTAL LENGTH | NUMBER OF VEHICLES | VEHICLE AREA | CARGO AREA | DECK AREA | SPIRAL RAMP AREA | TOTAL AREA | STOWAGE FACTOR |
|---|---|---|---|---|---|---|---|---|---|---|
| **Single Level- PALLETIZED** | 172 ft | 414 ft | 519 ft | 80 | 38,400 ft^2 | 71,208 ft^2 | 10,898 ft^2 | 0 ft^2 | 82,106 ft^2 | 47.0% |
| **Single Level-ANGLED** | 172 ft | 531 ft | 596 ft | 80 | 38,400 ft^2 | 91,280 ft^2 | 4,344 ft^2 | 0 ft^2 | 95,644 ft^2 | 40.2% |
| **Single Level- ANGLED: ACTUAL SHIP DESIGN** | 172 ft | 592 ft | 684 ft | 80 | 38,400 ft^2 | 100,478 ft^2 | 0 ft^2 | 0 ft^2 | 100,477 ft^2 | 38.2% |
| **Elevator- PALLETIZED-91' BEAM-3 DECKS** | 91 ft | 455 ft | 554 ft | 84 | 40,320 ft^2 | 124,215 ft^2 | 5,874 ft^2 | 0 ft^2 | 130,089 ft^2 | 31.3% |
| **Elevator- PALLETIZED-106' BEAM-3 DECKS** | 106 ft | 455 ft | 554 ft | 84 | 40,320 ft^2 | 144,690 ft^2 | 6,580 ft^2 | 0 ft^2 | 151,270 ft^2 | 26.7% |
| **Elevator- ANGLED-106' BEAM-3 DECKS** | 106 ft | 446 ft | 523 ft | 84 | 40,320 ft^2 | 141,828 ft^2 | 6,168 ft^2 | 0 ft^2 | 147,996 ft^2 | 27.3% |
| **1 Full Spiral-PALLETIZED-3 DECKS** | 106 ft | 332 ft | 449 ft | 84 | 40,320 ft^2 | 105,576 ft^2 | 8,088 ft^2 | 16,188 ft^2 | 129,852 ft^2 | 31.1% |
| **1 Full Spiral-ANGLED-3 DECKS** | 106 ft | 485 ft | 600 ft | 84 | 40,320 ft^2 | 154,230 ft^2 | 10,356 ft^2 | 19,437 ft^2 | 184,023 ft^2 | 22.0% |
| **2 Full Spirals- PALLETIZED- 3 DECKS** | 106 ft | 371 ft | 527 ft | 84 | 40,320 ft^2 | 117,978 ft^2 | 0 ft^2 | 32,376 ft^2 | 150,354 ft^2 | 26.8% |
| **2 Full Spirals- ANGLED- 3 DECKS** | 106 ft | 524 ft | 680 ft | 84 | 40,320 ft^2 | 166,632 ft^2 | 0 ft^2 | 38,874 ft^2 | 205,506 ft^2 | 19.6% |

Table Showing Various Areas in Relation to the Total Area

| ARRANGEMENT DISCRIPTION | % VEHICLE/TOTAL AREA | % CARGO/TOTAL AREA | % DECK/TOTAL AREA | % SPIRAL RAMP/TOTAL AREA |
|---|---|---|---|---|
| **Single Level- PALLETIZED** | 46.8% | 86.7% | 13.3% | 0.0% |
| **Single Level-ANGLED** | 40.1% | 95.4% | 4.5% | 0.0% |
| **Single Level- ANGLED APPLIED TO SHIP DESIGN** | 38.2% | 100.0% | 0.0% | 0.0% |
| **Elevator- PALLETIZED-91' BEAM-3 DECKS** | 31.0% | 95.5% | 4.5% | 0.0% |
| **Elevator- PALLETIZED-91' BEAM-DECK 1** | 28.4% | 87.6% | 12.4% | 0.0% |
| **Elevator- PALLETIZED-91' BEAM-DECK 2** | 32.5% | 100.0% | 0.0% | 0.0% |
| **Elevator- PALLETIZED-91' BEAM-DECK 3** | 32.5% | 100.0% | 0.0% | 0.0% |
| **Elevator- ANGLED-91' BEAM-3 DECKS** | ~~~~ | ~~~~ | ~~~~ | ~~~~ |
| **Elevator- PALLETIZED-106' BEAM-3 DECKS** | 26.7% | 95.7% | 4.3% | 0.0% |
| **Elevator- PALLETIZED-106' BEAM-DECK 1** | 24.5% | 88.0% | 12.0% | 0.0% |
| **Elevator- PALLETIZED-106' BEAM-DECK 2** | 27.9% | 100.0% | 0.0% | 0.0% |
| **Elevator- PALLETIZED-106' BEAM-DECK 3** | 27.9% | 100.0% | 0.0% | 0.0% |
| **Elevator- ANGLED-106' BEAM-3 DECKS** | 27.2% | 95.8% | 4.2% | 0.0% |
| **Elevator- ANGLED-106' BEAM-DECK 1** | 25.1% | 88.5% | 11.5% | 0.0% |
| **Elevator- ANGLED-106' BEAM-DECK 2** | 28.4% | 100.0% | 0.0% | 0.0% |
| **Elevator- ANGLED-106' BEAM-DECK 3** | 28.4% | 100.0% | 0.0% | 0.0% |
| **1 Full Spiral-PALLETIZED-3 DECKS** | 31.1% | 81.3% | 6.2% | 12.5% |
| **1 Full Spiral-PALLETIZED-DECK 1** | 30.6% | 80.2% | 7.5% | 12.3% |
| **1 Full Spiral-PALLETIZED-DECK 2** | 31.3% | 81.9% | 5.6% | 12.6% |
| **1 Full Spiral-PALLETIZED-DECK 3** | 31.3% | 81.9% | 5.6% | 12.6% |
| **1 Full Spiral-ANGLED-3 DECKS** | 22.1% | 84.4% | 5.0% | 10.6% |
| **1 Full Spiral-ANGLED-DECK 1** | 21.9% | 83.8% | 5.6% | 10.6% |
| **1 Full Spiral-ANGLED-DECK 2** | 22.1% | 84.7% | 4.6% | 10.7% |
| **1 Full Spiral-ANGLED-DECK 3** | 22.1% | 84.7% | 4.6% | 10.7% |
| **2 Full Spirals- PALLETIZED- 3 DECKS** | 26.8% | 78.5% | 0.0% | 21.5% |
| **2 Full Spirals- PALLETIZED- DECK 1** | 26.8% | 78.5% | 0.0% | 21.5% |
| **2 Full Spirals- PALLETIZED- DECK 2** | 26.8% | 78.5% | 0.0% | 21.5% |
| **2 Full Spirals- PALLETIZED- DECK 3** | 26.8% | 78.5% | 0.0% | 21.5% |
| **2 Full Spirals- ANGLED- 3 DECKS** | 19.6% | 81.1% | 0.0% | 18.9% |
| **2 Full Spirals- ANGLED- DECK 1** | 19.6% | 81.1% | 0.0% | 18.9% |
| **2 Full Spirals- ANGLED- DECK 2** | 19.6% | 81.1% | 0.0% | 18.9% |
| **2 Full Spirals- ANGLED- DECK 3** | 19.6% | 81.1% | 0.0% | 18.9% |


Stowage Factor for Alternative Cargo Arrangements
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
100% Selective
Dense Packed
Single Tier
Decks + Elevators
Decks + Spirals
Single Level-PALLETIZED
Single Level-ANGLED
Single Level-ANGLED APPLIED TO SHIP DESIGN
Elevator-PALLETIZED-91 BEAM-3 DECKS
Elevator-PALLETIZED-106' BEAM-3 DECKS
Elevator-ANGLED-106' BEAM-3 DECKS
1 Full Spiral-PALLETIZED-3 DECKS
1 Full Spiral-ANGLED-3 DECKS
2 Full Spirals-PALLETIZED-3 DECKS
2 Full Spirals-ANGLED-3 DECKS
LMSR
Commercial Car Parking (ASRS)
High Speed Sea Lift (Trimaran)


Comparison of Arrangements for 100% Selective Offload:
Graphing Beam, Cargo Deck, and Total Length
Beam
Cargo Deck
Total Length
800 ft
700 ft
600 ft
500 ft
400 ft
300 ft
200 ft
100 ft
ft
Feet
Single Level- PALLETIZED
Single Level-ANGLED
Single Level- ANGLED APPLIED TO SHIP DESIG.
Elevator- PALLETIZED-91' BEAM-3 DECKS
Elevator- PALLETIZED-106' BEAM-3 DECKS
Elevator- ANGLED-106' BEAM-3 DECKS
1 Full Spiral-PALLETIZED-3 DECKS
1 Full Spiral-ANGLED-3 DECKS
2 Full Spirals- PALLETIZED- 3 DECKS
2 Full Spirals- ANGLED- 3 DECKS
Arrangement Description


hing
210,000 ft^2
180,000 ft^2
150,000 ft^2
120,000 ft^2
90,000 ft^2
60,000 ft^2
30,000 ft^2
0 ft^2
Square Feet
ALLETIZED
el-ANGLED
Single Level- ANGLED APPLIED TO SHIP DESIGN
Elevator- PALLETIZED-91' BEAM-3 DECKS
Elev LLETIZE 106' BEAM-3 DECKS
Elev GLED-10 ECKS
1 Full LLETIZE S
1 Full Spiral-ANGLED-3
2 Full Spirals- PALLETIZED- 3 DECKS
2 Full Spirals- ANGLED- 3 DECKS
Arrangement Description
VEHICLE AREA
CARG
DECK
SPIRAL RAMP AREA
TOTAL AREA

## Annex L - Trip Reports

20.1.12 Attached are trip reports ; Hoboken and OTC 03 Conference

**Naval Surface Warfare Center, Carderock**

NSWC Carderock Division
9500 MacArthur Blvd
Bethesda, MD 20817

Prepared By:
Amber C Huffman
29 April 2003

# Garden Street Parking Garage

## 22 April 2003, Hoboken, New Jersey

Attendees: Ryan Hayleck
Amber Huffman
Met With: Harold L. (Hal) Reilley, Senior Sales Engineer
Phone: (808) 946-3682
Email: hal@lava.net

EXECUTIVE SUMMARY
We went to Hoboken, New Jersey to observe an automatic parking garage that was developed by Robotic Parking. This is the only garage of its kind in the US. The system was originally designed and implemented by Krupp in Germany and was brought to the U.S. and perfected by Robotic Parking. The purpose of this visit was to investigate how the system works and to determine the possibility and usefulness of adapting the current system to a ship. We determined that it would be possible to make the system sea worthy. The vehicles would need to be lashed to the pallets, and then the pallets would need to be latched or connected to the pallet carriers to accommodate high sea states.

SYSTEM BACKGROUND
The garage is located in the center of a residential neighborhood, on a lot where 5 row houses used to stand. The outside façade looks like an apartment building. The parking garage is 100X100 and holds 312 Cars, the largest being a GMC

Yukon/Chev Tahoe. With the size being 100x100, a conventional garage was not possible, since it typically takes up a block of land. The garage has 7 levels, 2 vertical lifts, 2 pallet carriers per row, 1 pallet lift, 1 pallet buffer and 4 entry/exit bays. For optimum use, 1 pallet shuttle for every 3 entry/exit bays, 1.5 entry/exit bays per vertical lift, and 1 carrier for every vertical lift per row. The system can reach a maximum of 20 levels, any length, but is optimized at a width of 100 feet. There are two different size decks; high- 8 feet, and low- 6 feet. However, if a scanner reports that a car is 6 feet, it will be taken to the high deck. To increase through-put, you can add more entry/exit bays, carriers and vertical lifts. In this system, 14 cars can move at one time but bottlenecks sometimes form at the vertical lifts. Although the vertical lifts move at 6 seconds per level. To park in this garage, it cost $235/month, compared to an average of $250/month at conventional garages in Hoboken, NJ.

To park a car, the car drives down the street, and their card, which is programmed with their customer number is read by a sensor posted on a light pole. One of the 4 bays then opens and shows a green light for the driver to pull in. For safety, the garage ask that only the driver pulls into the actual bay. The bay is housed with lasers measuring the car. If the lasers are blocked, the system produces a red light and new instructions for the driver to center the car on the pallet. Once all is clear, the driver puts the car in park, turns off the alarm, and exits the bay and swipes their card on their way out. The computer then logs the number and moves the car into the garage. Once the car is placed on the pallet, it always stays on that pallet until it leaves the garage. As it enters the garage, the car is turned 180 degrees by a turn table and then picked up by a pallet carrier, taken to a vertical lift and stowed in a spot.

The top portion of the pallet carrier rolls into the spot where the pallet is lowered 1 inch to rest on steel beams. The top portion of the pallet carrier then returns to its base. Each carrier has 4 motors, 2 in/out, and 2 back/forth. Gear boxes must be serviced every 25 years. Although, the computer will notify operator of potential problems and needed maintenance depending on hours in operation. The entire system is built for redundancy. If a carrier breaks, the other one can move it out of the way and continue working. However, if a carrier breaks down it is difficult to reach the corner spots, so those are filled last and only if the garage is completely full. All parts are commercial and off the shelf and Robotic Parking own the patent Robotic Parking system.

The computer determines where the car is stowed by its frequency data base. More frequent cars are placed in the front row. The typical time for a complete retrieval or stowage of a vehicle on the front row is 2.5 minutes and the back row is 3.5 minutes. Since it is a residential garage, there are two main types of users; daily and weekend. Personnel switch up the arrangement on Friday at midnight, in anticipation of the weekend users needing their cars on Saturday morning. The system is then rearranged Sunday night to get ready for rush hour on Monday. A program is being developed for the computer to do this automatically.

To retrieve a car, the owner walks into the lobby, scans their card and types in a security code. The system is cued, and then returns a message on the marquee telling the driver which bay the car will appear in. Inside the garage, the vertical lift travels to the level where the car is stored while the carrier is moving to pick up the car. The carrier releases the pallet to the vertical lift, travels to the ground floor, and then is transported to another carrier which takes it to the respective bay. The car travels into the bay area, the door opens, driver gets in and drives out. No need to back up, the position of the car was adjusted when it entered the bay to save time when the car was retrieved. If the car was on the second row of a level, one carrier would pick up the first car and move it out of the way, while the other carrier retrieved the requested car. This process would take an extra minute.

Once the car leaves the pallet, the empty pallet drops down and is stored there until 4 empty pallets arrive. Once 4 pallets are in the hold, a pallet bundler is cued to pick up the bundles and move then to an empty spot. The pallets stay there until the computer is cued to pick up a bundle and place it in hold to feed the in entry bay. Within 45 seconds, a new pallet is in place awaiting a car. In the morning there are 3 exit bays and 1 entry bay, and in the afternoon there are 3 entry bays and 1 exit bay. However the bays can be switch with a click of a mouse on the operators computer.

The computer is run using Simplicity software. The operator screen can be accessed online from any remote location. The computer that actually controls the system is completely stand alone. An operator monitors it during rush hour in case of problems. But it makes most moves itself. There are sensors on everything to trigger maintenance and other issues. Also shows revolutions for each carrier, once each hit 1 million, notice for maintenance pops up. System updates every .5 seconds. Can pull up driver and frequency database at anytime. Everything is simply monitored, and changed manually be the click of a mouse. Cars are color coordinated depending on frequency and height for easy monitoring.

The cost for this system was 6.2 million dollars and it took a year to build. However, there were several political issues that delayed the process. The garage is also set up to have maintenance bays, such as oil changes and car wash options available. Some applications have been looking at installing bomb detectors. Anything is possible, just depends on the budget! The system is modular and everything can be reconfigured except for the vertical lift and aisle space. There have been no complaints from neighbors concerning noise.

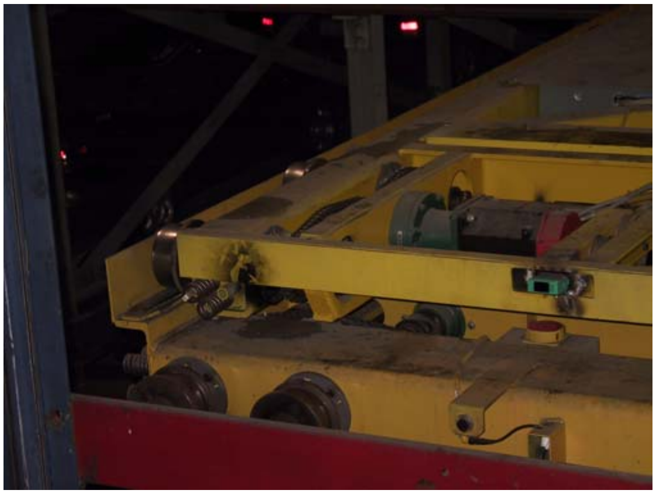
What the operator felt should be changed in future garages: 2 pallet lifts and do away with the pallet buffer, better system to position vertical lifts- more heavy duty chains instead of the counter weight system, better lasers to line up with carriers instead of using holes like now, and the steel alignment. They are currently working on installing a new sensor system to read the cards once the vehicle is clear, so driver doesn't have to scan card manually.

Robotics Parking was not the general contractor on this project. As a consequence, there are problems with the steel design. The system is set up for a 2-3 mm tolerance concerning rail guidance. But in some places, the steel is off-line as much as 12mm. As a result the system has learned to compensate for this mistake. However when the carriers travel straight across from the vertical lifts to the entry/exit bays, they must stop at a point to realign the path. This is a

result of poor design on the contractors part. But shows that the system can adjust.
The optimum width of this type of garage is 100 feet, but the length can vary. Each level can also be wedding caked to adapt to available space. If this system was used within a ship, ventilation systems could be minimal within certain hulls since vehicles will be turned off and fumes will not be produced.
There are 4 cameras throughout the garage: in the lobby, entry/exit bay, 4th floor and 7th floor of garage. Camera views are available on operators screen as well as for online demonstrations upon request.
For more information: www.roboticparking.com

Pallet Carrier

Car stowed on pallet in second row



View of pallet carrier mechanisms
More pictures and video clips are available.

**Naval Surface Warfare Center, Carderock**

NSWC Carderock Division
9500 MacArthur Blvd
Bethesda, MD 20817

Prepared By:
Amber C Huffman
2 May 2003

# Summit Grand Parc Parking Garage

## 2 May 2003, Washington, DC

Attendees: Ryan Hayleck
Amber Huffman
Peri Perkins
Jon Wrinn

Met With: Jack Latrowski, General Manager, Mid-American, Alexandria Office
Phone: 202-438-3058 (cell)
Email:

EXECUTIVE SUMMARY

We went to an apartment complex in Washington, DC to observe an automatic parking garage that was developed by Space Saver Parking and Mid-American Elevators. The system was manufactured by WORH Auto Park Systems. The purpose of this visit was to investigate how the system works and to determine the possibility and usefulness of adapting the current system to a ship. We determined that it would be possible to make the system sea worthy. This system proved to be a simpler than the Robotic Parking System we investigated in Hoboken, New Jersey. The components are less intricate and should be easier to make sea worthy.

SYSTEM BACKGROUND

The automated garage is based on warehouse technology. The automated garage at Summit Grand Parc holds 74 vehicles, whereas had a traditional garage with ramps been used, only 20 cars could have been parked. The design has two rows of vehicles stacked 4 high with a lane between for the lift to access the vehicles. This allows for complete 100% selective offload. The lift is moves laterally on rails. The lift is chain driven and uses counter weights.

Customer drives car onto the pallet. Sensors determine whether the vehicle is a car, SUV, or if it is too tall. Laser sensors on the ceiling check to make sure the car is completely on the pallet. The customer exits the vehicle and the entrance bay and enters in a code telling the computer to take the car. Motion sensors in the entrance bay make sure everyone has left and then the pallet is rotated 15 degrees, so that it is flush with the pallet hole located on the top level of the garage. Entrance and exit bays are at an angle due to limited room in building.
A lift pulls the pallet off the rack using friction rollers and at the same time places an empty pallet back on the rack for the next car entering the garage. The lift then brings the vehicle to an empty space. The lift rolls the pallet onto the rack and at the same time removes the empty pallet in that space to replace the pallet in the entrance bay when another vehicle enters. The lift can raise/lower the vehicle as it moves down the lift lane.
The cycle to retrieve a car is 2.5 minutes. There are two entry/exit bays, where system can determine rather the bay is in or out depending on the demand by the tenants. Bottlenecks in the system occur at high transient times including the morning and evening rush hour. At one point there maybe 20 or more people requesting there cars at once which leads to down time for the tenants. However, the benefits outweigh the disadvantages and the car parking system is both cost effective and valuable to the residents. If for some reason the building lost power, the system has its own backup generator to run the motors and lifts so tenants can retrieve their cars at any time. Maintenance is minimal and includes scheduled lubrication and visual inspections. The system is completely automated and does not require any personnel under normal operating conditions. The system has proven reliability over its lifecycle to both the tenants and building management.
System can be configured to meet needs. Can be designed to match desired throughput levels and vehicle sizes. More elevator lifts and entry/exit bays would be added.

Garage layout and view of pallets and stacks.

Turn table and pallet in entry and exit bay.

View of pallet on elevator lift.

View of pallet transfer mechanisms from elevator to storing racks.
Video and additional pictures available upon request.

**Naval Surface Warfare Center, Carderock**

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Prepared By:
Amber C Huffman
9 May 2003

# Offshore Technology Conference

## 5-9, May 2003, Houston, TX

Attendees: Michael Gilbertson, MOD
Ryan Hayleck, 2820
Amber Huffman, 2820
Mark Selfridge, MOD

EXECUTIVE SUMMARY

The purpose to attending the Offshore Technology Conference (OTC) in Houston, Texas was to learn how the offshore industry operated in certain environments and conditions. Over 45,00 participants attended during the week.

There were over 350 papers presented through-out the conference, as well as a large trade show housing over 1250 vendors. Most of the papers were not relevant. However, the session on spar design and FPSO(Floating Production Storage Offshore) systems were very interesting and useful. Picked up a lot of useful info there about the sizing of the strakes and the benefits of having them from a motion perspective. Information received is hoped to be useful in answering several questions and concerns that have developed within the Seabasing Innovation Cell. Some topics of interest included:

- Re-configurable spaces and containerized units- Able to look inside and get a good feel for the services
- Heavy lift ship stability
- Float On/Float Off ships- Received some useful info and met some people the team had been emailing previously. Got an offer of stability booklets, curves, lines plans etc which needs to be followed up on managing of large heavy and bulky loads
- Craneships
- Spar design and motions
- Dynamic positioning
- Personnel transfer- the “frog”
- Multi-purpose catamaran design
- Elevators
- Seakeeping Programs

We would recommend for future years, that 2/3 days would be enough, no need for a full week. Proceedings CD from the presentations is available upon request.

General Exhibits Visited

- GIRASSOL- Deepwater and general information
- Village Marine Tec.- Pure Water Purifying Systems
- ITRONIX- Strong/Waterproof Computers
- Panasonic- Tough Book Computer
- Diagnostic Instruments- Rugged Handheld Computers
- AllSEAS- Craneships- Mooring
- ABS- Offshore Classification and Certification Services
- Industrial Services
- NMA Maritime and Offshore Contractors Inc.- semi submersibles
    a. Mark van Meel, 281-497-4300
- Champion Elevators
    a. Herbet Calles Linck- 713-640-8500
- Multi-Purpose Supply Vessels
- Deepwater Offtake Systems
- Boabarge 20- Heavy Lift and submersibles
- SESAM-Simulators for Complex Marine Operations
- WhiteHill- ropes and chains
- Bender- Shipbuilding and Repair Co.- cranes, large ships, docking
- Dockwise- Semi submersible Heavy Lift Ship Operations
- Alabama Shipyard- Barges, tugs, and deep well cargo pumps
- Huisman-Itrec- Multipurpose Catamaran, Cable tensioning and motion compensation systems, and marine and offshore cranes
- LIEBHERR- Offshore crane delivery program
- Ostensjo Rederi AS- supply and heavy lift ships, and multi-purpose
- SEAWARD- Marine Fenders
- Fentek- Marine Fenders

## Dynamic Positioning

- Thrustmaster of Texas Inc.-Hydraulic outboard thrusters, azimuthing thrusters, and portable dynamic positioning systems

## Personnel Carriers

- Reflex Marine- FROG Personnel Transfer Carrier
- POWERQUICK- Personnel Lifting System- Currently under SBIR contract (www.quointech.com)
- Segway HT's and Accessories- personnel carriers
- Viking Life-Saving Equipment- Offshore Evacuation Systems

## Related to Re-configurable Spaces

- Containerhouse International, Inc- Control rooms, workshops and storage, living quarters, dnv and A60 buildings, equipment enclosures, services, accessories, custom housing available (www.containerhouse.com)
    a. George Vernau Jr. (281) 478-0505
- General Marine Leasing- Galley, diner, portable housing, custom built, units for rent. ( www.generalmarineleasing.com )
    a. Soule Leone, Yard Superintendent (504) 394-1155
    b. Charles Macaluso III, Senior Sales Executive (504) 394-1155
- Duffy & McGovern- Accommodation Services- Sleepers, portable water tanks, external stairs, lighting, sewage treatment plants, generators, power distributions, offices, galley, mess, laundry, and freezer. (www.dm-accomodation.com)
    a. Glenn Aguilar, VP US Operations, 504-392-9411
- Safe Haven Enterprises, Inc- Blast Resistant Buildings
- MB Industries- SeaShelters- Coast Guard approved buildings, recreation rooms, sleepers, diners, galley, restrooms, servers, control buildings, logging units portable labs, and custom designs. (www.mbindustries.com )

a. Chris Vallot, 337-334-1900 or 1-866-334-1904

- Deansteel – Manufacturer of marine furniture, berths, galley and laundry equipment, steel doors, and panel bulkheads. (www.deansteel.com )
    a. Wolfgang Avery, 1-800-825-8271

## Publications

- Offshore Oil Map
- Oilweek Magazine
- Upstream Oil and Gas Newspaper

## Upcoming Conferences/Trade Shows

- Opportunity and Innovation in Louisiana (OIL)- Dec 3-5, 2003
- Offshore Northern Seas- Stavanger, Norway- 24-27 August 2004

## Presentations Attended

- BARRACUDA/CARATINGA Project
    - Barracuda and Caratingua Integrated Deepwater Site Investigation, Offshore Brazil
    - Geotechnical Design of the Barracuda and Caratingua Suction Anchors
    - P43/P$48 Global Motion and Stability Analysis: A Compromise Combination to define the FPSO Operational Behavior
- IMPACT OF VIV ON SPAR DESIGN
    - The Cell Spar and Vortex Induced Vibrations
    - Model Test Experience on Vortex Induced Motions of Truss Spars
    - Mooring Design for Directional Spar Hull VIV

- FPSO Construction and Repair
    - New Build Generic Large FPSO
    - Development of Load-Out Methodology for On-Ground Build FSO
    - A Solution for FPSO Module Integration

## Annex M - Meeting Notes (Mr K McAllister)

20.1.13 Attached are the main points from a meeting with Mr Keith McAllister on 25 February 2003;

Meeting Review: Main Points

1. Falklands lessons learned
2. Falklands as model of seabasing in expeditionary warfare
3. Standoff vs. Survivability Report
4. Seabase must not rely on moored platforms
5. Reconstitution requires space, repairs, resupplying vehicles
6. Extraction will probably use contractors
7. At sea large missile reloading
8. Selective Offload
9. Dynamic positioning system/thrusters important
10. Points of contact:
    a. Bob Ramsey, Dave Helgerson (Seabase Demo Ship)
    b. Jack Offutt (MCCDC contact)
11. Relative motion is the critical technical problem
12. Offshore industry distribution systems/models
13. Cargo Tracking – becoming more important – big problem with Desert Shield
14. First phase – RO/RO Sustainment – Boxes
15. Convertible containership – Bell Pioneer (Irish Sea) – High sided – FWD deckhouse – hatchless containership
16. Cranes – Designed for heavy loads to lift lighters and ramps – No cranes in service on Navy ships designed for rapid transfer
17. Seabase/UNREP/JLOTS – Lots of common ground
18. VLMOB and SL7 Model testing – some waves get through.
19. Mooring semisub Samson and standoff mooring systems – How does supply boat (140 – 230ft, designed for seakeeping and cargo capacity) come up alongside semisubs.
20. Conversion of LMSR – unclassified report – Keith to email CK
21. Funnel to capture container – see Art
22. Big move to get away from palletized ammunition towards containerized ammo (half-highs)
23. Demonstrations – Let operators “play” with concepts to test
24. Lightering – Gulf of Mexico – VLCC’s to handy size
25. SEABEE’s/ lash ship
26. JLOTS – Number of distribution points, throughput rate, cranes, deck crew etc.

## Annex N - Meeting Notes (Mr A Rausch, Mr J Strickland)

20.1.14 Attached are the main points from a meeting with Mr Art Rausch and Mr Jason Strickland on 27 February 2003;

Minutes for Meeting on Limiting factors for Transfer at Sea
Sea Basing Innovation Cell NSWCCD

**27th February 2003**

Attendees: Art Rausch, Jason Strickland, Sea Basing Innovation Cell Members
Limiting Factors for Transfer at Sea
Relative Motions
Skin to Skin evolutions

Cranes
Pendulation
Operator Skill levels (Reserve Personnel)
Heel Angle (Generally designed to take major loads normally)
It is noted however that cranes can generally operate at higher seastates than ramps.

Factors specific to Non-Military Vessels
interface compatibility
crew training

Position of Ramps

- Stern Ramps

(Most navy vessels will have stern ramps that can be slewed, while commercial vessels will be restricted by having fixed quarter ramps)

- Side Ramps

(Side ramps are not generally a problem from the structural damage point of view as operations are usually conducted in the lee of the ship. The effect of side ramps on cargo flow within the ship is greatly effected)

Movement of Ramps

- Lateral Movement (Subsequent Stresses imposed on Hinge Pins)
- Fore & Aft Movement ( Not Critical)
- Interface Frictional Damage (Mitigated by Wooden Dunnage or Low Friction Polyethylene)
- Stronger, Stiffer ramps are not necessarily better. More flexible systems may need to be analysed.

Personnel Safety

- Risk of Personnel being swept away

- Risk due to wind during crane operations

Lighters

- Freeboard in the Deep Condition
- Motions

Selective Pickup & Selective Offload (SP& SO)

Chemical, Biological and Radiological (CBR)

- Decontamination

Airlift Capacity

- Capability Gap for airlift of vehicles larger than a Humvee

## Topics Discussed

Reconstitution
This will cover the repair of equipment damaged or disabled in service. In addition equipment that cannot be repaired will require delivery to allow scrapping to take place. This is not anticipated to be a major area of concern.
Non – Military Salvage and Repair (Concept Only)

MPF & MPF(F) Status

MEB – Marine Expeditionary Brigade
Currently not all supplies are moved by sea, a number of delivery sorties using heavy lift transport are required, These may number several hundred sorties and are typically limited to high value, low density cargoes.

Decision to halt Transfer Operations
This is taken by the ships Captain and is affected by likelihood of:
Damage to ship
Pendulation likely to cause damage or excessive danger to personnel
Motions that cause both damage to the ramp and vessels interfacing the ramp.

Commercial Vessels
It is likely that a seabase will have to allow interface with vessels other than military ships. This poses issues as identified in the limiting factors above, re: Personnel training, compatibility.

Risks
Currently the 3’ to 5’ waves are seen as the main dangers in the transference of equipment. This is reduced to much lower levels where the transfer of personnel is required. These waves, while small, are large in comparison with the freeboard available on most barges and lighters. The risk to personnel is highest during periods of shift change, where personnel may not have the protection afforded by their station. The use of ladders is also more frequent at this time and where it is

too rough to use fixed ladders  it is common to use Jacobs Ladders (rope ladders).
There are also risks associated with the need for personnel to drive vehicles up ad down ramps. Options that have been studied include methods of holding the vehicle to the ramp, or moving the vehicle on a trolley arrangement

**Related Studies**
Information on the uses and limitations of side ramps were investigated by Code 55, NSWCCD
Ramp Platform Interface studies have been conducted by Frank Leban. These looked into the use of gimbaled hinges as a means of dealing with ship motions.
The recent JLOTS conference covered work which developed a ramp with "fingers" for use as the interface between INLS and a INLS ferry
Work by MARAD produced a system where stress and strain within the ramp is indicated by a warning system.

**Contacts**
Underway Replenishing
Marvin Millar
George Lyons (will be attending Navy Operational Logistics Conference, end of March 2003)

Packaging, Handling, Stowage and Transfer
Nick Laken – Naval Weapons Station Earl (New Jersey)
Greg Bender – Naval Weapons Station Earl (New Jersey)
DLA – Mechanicsburg, Pennsylvania
NAVSUP / NAVICP – Developmental Efforts

Shipboard Machinery Systems, Cargo Tracking Systems
Steve Machetti, NAVSUP Philidelphia

**Proposed Deliverables**
There are a number of mission scenarios that have been worked up in detail as part of previous projects. These include details of typical forces involved, structure of deployed forces, numbers of personnel and quantities of equipment etc. Jason Strickland was identified as being able to provide access to reports detailing this information.

## Annex O - Concepts from Brainstorming

20.1.15 Attached is a list of the 50 or so concepts that the team identified through brainstorming; these were then grouped (see table below) with ‘like’ concepts to allow some initial research to aid down-selection;

## Seabase Cargo Transfer Brainstorm Session

**March 6, 2003**

**Attendees:**

Mark Selfridge
John Jacobsen
Ryan Hayleck
Owen Ritter
Amber Huffman
Gary Hall
Michael Gilberston
Paul Hawkins
Colen Kennell

**Concept Ideas:**

1. Owen: offload time critical, envision very large high SWATH, boats come between the hulls, everything internal, lighter launch/retrieval between hull

2. Gary: Intermediate cargo transfer platform

3. Mike: Well deck arrangement

4. Paul: small heavy lift ship

5. Colen: troop shuttle ship

6. Mark: Skin to Skin vehicle/container ramp

7. John: lighter motion matching crane

8. Ryan: Spreader bar messenger system

9. Owen: Modular seabase elements

10. Amber: Flexible ramp

11. Gary: CONREP stations on seabase
12. Michael: Bear trap for lighters
13. Paul: UAV for helo mission
14. Colen: Evacuation chute personnel transfer
15. Mark: Spar buoy crane ship
16. John: floating dry dock/beach
17. Ryan: ramp torsion relief
18. Amber: vehicle turn table
19. Michael: Motion compensated ramp
20. Paul: inflatable interfaces
21. Colen: wave energy extraction
22. Mark: stabilized intermediate transfer system
23. John: zero speed active/passive stabilization
24. Ryan: snag-free tag line system
25. Owen: movable cargo decks
26. Amber: Gantry crane with soft landing
27. Gary: Crane captured lighter
28. Mike: Semi submersible crane ship
29. Paul: vacuum packed cargo
30. Colen: Advanced Logistics Delivery System
31. Mark: Container Gantry Crane
32. John: Flexible guide rails
33. Ryan: Two vessel gantry crane (Mark: One vessel)

34. Owen: Deployable, inflatable bridge
35. Amber: Modular containerized crane
36. Gary: Ship to ship worm hole
37. Michael: motion compensated ship to ship conveyor belt
38. Colen: sky hook
39. Mark: Inflatable barges
40. Mark: Seaborne high rate crane
41. Mike: Wet well wave cancellation
42. Amber: Containerized reach stacker
43. Amber: Dynamically controlled soft moored
44. Amber: Selective offload
45. Amber: Active wave cancellation
46. Mark: Elevators/Lifts
47. Colen: Partial lighter support elevators
48. Colen: Shipside lighter beach
49. Mark: High impact landing area
50. Mark/Amber: Efficient cargo landing station

| Grouping Number | Title | Description | Brainstorm ID Number |
|---|---|---|---|
| 1 | More Efficient Crane Concepts | Craneships & Cranes on Ships | 7,26,28,31,33,40 |
| 2 | Personnel Transfer | | 14 |
| 3 | Lighter Motion Reduction Concepts | Autonomous Thrusters, Small Heavy Lift Ships, Crane Captured Lighter, Soft Mooring, Elevators (External), Beach | 4, 12, 16, 22, 23, 27, 43, 47, 48 |
| 4 | Mini MOB | Self Deploy, Thinhull (SWATH), Helo Transfer, Benign Environment between hulls, Reconstitution Platform, Offload Platform, Lighter/LCAC/Helo Base | 1, 2 |
| 5 | Inflatable Structures Technology | Chutes | 20, 29, 34, 39 |
| 6 | Ramps | | 6, 10, 17, 19 |
| 7 | Modular Lighter - Shore Interface | | 42 |
| 8 | Improved Container / Crane Connection Concepts | Intelligent Spreaders | |
| 9 | Selective Offload Concepts | Turntable, Moveable Decks, Internal Lifts/Elevators, High Impact Landing Area, Efficient Cargo Handling Area | 25,44,46,49,50 |
| 10 | Wave Mitigation | | 21,45 |
| 11 | ALDS | | 30 |
| 12 | Active Packaged Transfer Concepts | Worm Hole & Conveyors | 36, 37 |

## Annex P - Cargo Types, Characteristics

20.1.16 Attached a consolidated matrix of cargo types and cargo characteristics;

| | CARGO CHARACTERISTICS | | | | |
|---|---|---|---|---|---|
| **CARGO TYPES** | Minimum Transfer Method | Rate | Hazardous | Self Mobile | Personnel Safety |
| Fuels | Highline | High | x | | x |
| Water | Highline | High | | | x |
| Containers | Crane | High | | | x |
| Vehicles | Ramp | High | | x | x |
| Pallets | Highline | High | some | | x |
| People | Gangway | Low | | | x |
| Casualties | Gangway | Low | | | x |
| Barrels | Highline | Low | some | | x |
| Bladders | Crane | High | some | | x |
| Boxes | Gangway | Low | some | | x |
| Ammunition | Highline | Medium | x | | x |
| Spares | Gangway | Low | | | x |
| Tools | Gangway | Low | | | x |
| Bulk | Crane | Low | | | x |
| Equipment | Crane | Low | | | x |
| Construction | Crane | Low | | | x |
| Humanitarian | Crane | Low | some | | x |
| Food | Crane | Medium | | | x |

# Annex Q - Platform versus Cargo Transfer Mechanism (Static)

20.1.17 Attached is a matrix of seabased platforms (supply and delivery) versus various cargo transfer mechanisms for the STATIC environment;

| STATIC | TRANSFER MECHANISMS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hose | Ramp | Crane | Highline | Gangway | Air Internal | Air External | Manual | Welldeck | Float On/Off | Causeway |
| **SUPPLY PLATFORMS** | | | | | | | | | | | |
| Tankers | 100% | | | | | | | | | | |
| Container Ships | | 10% | 90% | | | | | | | | |
| Ammunition Ships | | | 75% | 5% | | | 20% | | | | |
| Aircraft (Fixed) | | | | | | 100% | | | | | |
| Aircraft (Rotary) | | | | | | 30% | 70% | | | | |
| Dry Cargo Ships | | 50% | 50% | | | | | | | | |
| RO/RO Vessels | | 95% | 5% | | | | | | | | |
| Troop Carriers | | | | | 100% | | | | | | |
| HSV / TSV -> Intra-Theater | 20% | 70% | 10% | | | | | | | | |
| UNREP Ships | 30% | | 70% | | | | | | | | |
| High Speed Sealift | | 100% | | | | | | | | | |
| Craneships | | | 100% | | | | | | | | |
| **UTILISATION DURING SUPPLY OF SEABASE** | 150% | 325% | 400% | 5% | 100% | 130% | 90% | 0% | 0% | 0% | 0% |
| **RELATIVE IMPORTANCE** | 3 | 2 | 1 | 7 | 5 | 4 | 6 | 8= | 8= | 8= | 8= |

| **DELIVERY / EXTRACTION PLATFORMS** | Hose | Ramp | Crane | Highline | Gangway | Air Internal | Air External | Manual | Welldeck | Float On/Off | Causeway |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LCAC | | | | | | | | | 20% | | 80% |
| LCU | | | | | | | | | 20% | | 80% |
| Aircraft (Fixed) | | | | | | 100% | | | | | |
| Aircraft (Rotary) | | | | | | 30% | 70% | | | | |
| Small Assault Vehicles | | 100% | | | | | | | | | |
| RIBS / PC / Small Boats | | | 100% | | | | | | | | |
| HSV / TSV -> Intra-Theater | 20% | 70% | 10% | | | | | | | | |
| Troop Carriers | | | | | 100% | | | | | | |
| INLS - FC / RRDF / CF / WT | | 50% | 50% | | | | | | | | |
| Unmanned Vehicles UAV, UUV, USV | | | 100% | | | | | | | | |
| UNREP | 60% | | 30% | | | | 10% | | | | |
| Warships | 50% | | 30% | | | 5% | 15% | | | | |
| Barges | | 30% | 70% | | | | | | | | |
| Hospital Ships | 10% | | | | | 30% | 60% | | | | |
| Heavy Lift Ships | | | | | | | | | | 100% | |
| Submarines | | | 90% | | 10% | | | | | | |
| Salvage Vessels | | | 100% | | | | | | | | |
| **UTILISATION DURING DELIVERY / EXTRACTION** | 140% | 250% | 580% | 0% | 110% | 165% | 155% | 0% | 40% | 100% | 160% |
| **RELATIVE IMPORTANCE** | 6 | 2 | 1 | 10= | 7 | 3 | 5 | 10= | 9 | 8 | 4 |

| | Hose | Ramp | Crane | Highline | Gangway | Air Internal | Air External | Manual | Welldeck | Float On/Off | Causeway |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **OVERALL UTILISATION** | 290% | 575% | 980% | 5% | 210% | 295% | 245% | 0% | 40% | 100% | 160% |
| **RELATIVE IMPORTANCE** | **4** | **2** | **1** | 10 | 6 | **3** | **5** | 11 | 9 | 8 | 7 |

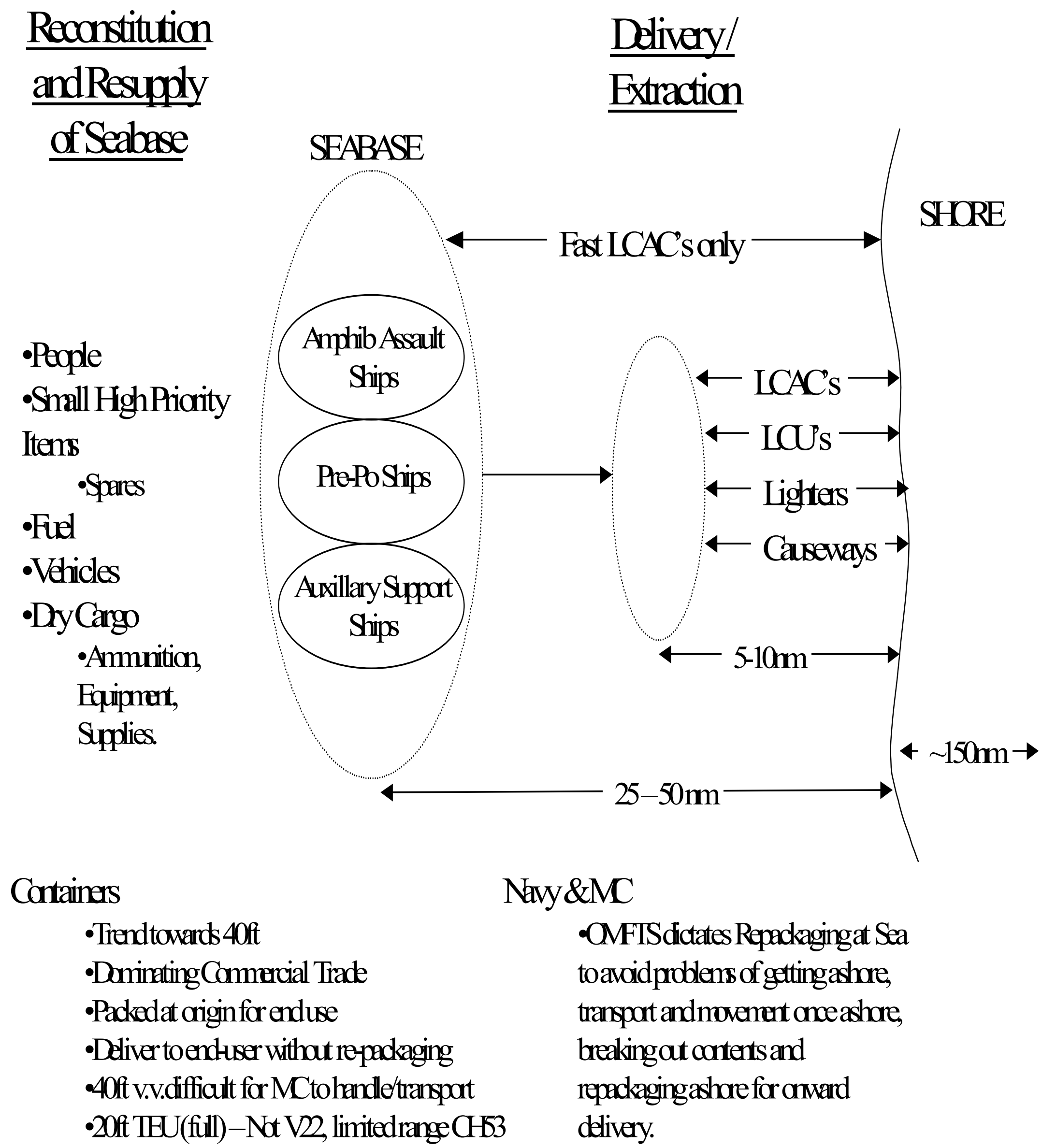
# Annex R - Platform versus Cargo Transfer Mechanism (Underway)

20.1.18 Attached is a matrix of seabased platforms (supply and delivery) versus various cargo transfer mechanisms for the UNDERWAY environment;

| UNDERWAY | TRANSFER MECHANISMS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hose | Ramp | Crane | Highline | Gangway (compensated) | Air Internal | Air External | Manual | Welldeck | Float On/Off | Causeway |
| **SUPPLY PLATFORMS** | | | | | | | | | | | |
| Tankers | 100% | | | | | | | | | | |
| Container Ships | | 70% | 30% | | | | | | | | |
| Ammunition Ships (in Skin to Skin) | | 70% | 30% | | | | | | | | |
| Aircraft (Fixed) | | | | | | 100% | | | | | |
| Aircraft (Rotary) | | | | | | 30% | 70% | | | | |
| Dry Cargo Ships | | 70% | 30% | | | | | | | | |
| Troop Carriers (in Skin to Skin) | | | | | 100% | | | | | | |
| HSV / TSV -> Intra-Theater (in Skin to Skin) | | | | | 100% | | | | | | |
| **UTILISATION DURING SUPPLY OF SEABASE** | 100% | 210% | 90% | 0% | 200% | 130% | 70% | 0% | 0% | 0% | 0% |
| **RELATIVE IMPORTANCE** | 4 | 1 | 5 | 7= | 2 | 3 | 6 | 7= | 7= | 7= | 7= |
| **DELIVERY / EXTRACTION PLATFORMS** | | | | | | | | | | | |
| Aircraft (Fixed) | | | | | | 100% | | | | | |
| Aircraft (Rotary) | | | | | | 30% | 70% | | | | |
| Small Assault Vehicles (as cargo itself) | | 100% | | | | | | | | | |
| RIBS / PC / Small Boats (as cargo itself) | | | 100% | | | | | | | | |
| HSV / TSV -> Intra-Theater | | 70% | 30% | | | | | | | | |
| Unmanned Vehicles UAV,UUV,USV (as cargo itself) | | | 100% | | | | | | | | |
| UNREP | 60% | | 40% | | | | | | | | |
| Warships | 50% | | 30% | 10% | | | | | | | |
| Salvage Vessels | | | 100% | | | | | | | | |
| **UTILISATION DURING DELIVERY / EXTRACTION** | 110% | 170% | 400% | 10% | 0% | 130% | 70% | 0% | 0% | 0% | 0% |
| **RELATIVE IMPORTANCE** | 4 | 2 | 1 | 6 | 7= | 3 | 5 | 7= | 7= | 7= | 7= |
| **OVERALL UTILISATION** | 210% | 380% | 490% | 10% | 200% | 260% | 140% | 0% | 0% | 0% | 0% |
| **RELATIVE IMPORTANCE** | **4** | **2** | **1** | 7 | **5** | **3** | 6 | 8= | 8= | 8= | 8= |

## Annex S - Diagrammatic representation of OMFTS

20.1.19 The diagram bellows depicts OMFTS and highlights some of the container transfer issues;



## Annex T - Vehicle List and characteristics

20.1.20 Tabular summary of vehicle lists and characteristics.

| | | MEB | STOM | STOM | HSS | OUR | 1/6th | | | | | | | Deck | Item | Item | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | | 2015 | | SEABASE | | # | | Length (m) | Width (m) | Height (m) | Weight (mt) | Area (m2) | Volume (m3) | Load | Density | Density | WEIGHT |
| Engn Equipment | | | 285 | 248 | | 250 | 42 | 11.58 m | 2.44 m | 2.59 m | 15.0 mt | 28.3 m2 | 73.2 m3 | 531 kg/m2 | 0.205 mt/m3 | 205 kg/m3 | 630.0 mt |
| ABV | Assault Breaching Vehicle | | 5 | 5 | | 5 | 1 | 11.00 m | 3.66 m | 2.63 m | 70.0 mt | 40.3 m2 | 105.9 m3 | 1739 kg/m2 | 0.661 mt/m3 | 661 kg/m3 | 70.0 mt |
| AAAV | Adv Amphib Assault Vehicle | 106 | | 106 | 32 | 106 | 17 | 9.10 m | 3.66 m | 3.18 m | 28.5 mt | 33.3 m2 | 105.7 m3 | 857 kg/m2 | 0.270 mt/m3 | 270 kg/m3 | 485.0 mt |
| LAV | Light Armored Vehicle | 60 | 110 | 60 | 115 | 85 | 14 | 6.99 m | 2.67 m | 2.67 m | 15.7 mt | 18.6 m2 | 49.7 m3 | 844 kg/m2 | 0.317 mt/m3 | 317 kg/m3 | 220.2 mt |
| M1A1 | Main Battle Tank | 29 | 37 | 29 | 11 | 33 | 6 | 7.93 m | 3.66 m | 2.63 m | 57.2 mt | 29.0 m2 | 76.3 m3 | 1973 kg/m2 | 0.750 mt/m3 | 750 kg/m3 | 343.3 mt |
| LW155 | 155 mm Towed Howitzer (M198) | 18 | 18 | 18 | | 18 | 3 | 7.52 m | 2.82 m | 2.18 m | 8.0 mt | 21.2 m2 | 46.3 m3 | 377 kg/m2 | 0.173 mt/m3 | 173 kg/m3 | 24.0 mt |
| EFSS | Expeditionary Fire Support System | 8 | 24 | 8 | | 16 | 3 | 6.07 m | 2.21 m | 1.80 m | 10.8 mt | 13.4 m2 | 24.2 m3 | 802 kg/m2 | 0.445 mt/m3 | 445 kg/m3 | 32.3 mt |
| HIMARS | High Mobility Artillery Rocket System | 6 | 6 | 6 | 6 | 6 | 1 | 6.94 m | 2.40 m | 3.18 m | 13.7 mt | 16.7 m2 | 53.0 m3 | 822 kg/m2 | 0.259 mt/m3 | 259 kg/m3 | 13.7 mt |
| HMMWV- M1097 | Truck Utility Hvy- HMMWV | 743 | 1349 | 1034 | 165 | 1000 | 170 | 5.01 m | 2.18 m | 2.59 m | 3.9 mt | 10.9 m2 | 28.3 m3 | 353 kg/m2 | 0.136 mt/m3 | 136 kg/m3 | 656.6 mt |
| ITV | Internally Transportable Vehicle | 21 | | | | 21 | 4 | 1.52 m | 5.08 m | | 17.6 mt | 7.7 m2 | 0.0 m3 | 2278 kg/m2 | #DIV/0! | #DIV/0! | 70.5 mt |
| MTVR | Medium Tactical Vehicle Replacement (MK | 430 | 530 | 466 | | 480 | 80 | 9.82 m | 2.49 m | 3.57 m | 27.7 mt | 24.4 m2 | 87.3 m3 | 1134 kg/m2 | 0.317 mt/m3 | 317 kg/m3 | 2216.0 mt |
| LVS Mk48 | Logistics Vehicle System with trailer | 105 | 70 | 68 | | 85 | 14 | 11.58 m | 2.44 m | 2.59 m | 25.4 mt | 28.2 m2 | 73.2 m3 | 899 kg/m2 | 0.347 mt/m3 | 347 kg/m3 | 355.6 mt |
| M88A1 Recovery Veh | M88 Recovery Vehicles | | 9 | 7 | 1 | 9 | 2 | 8.21 m | 3.38 m | 3.40 m | 48.9 mt | 27.7 m2 | 94.4 m3 | 1764 kg/m2 | 0.518 mt/m3 | 518 kg/m3 | 97.9 mt |
| Comm Vech | | 247 | | | 12+12 | | | | | | | | | | | | |
| AAV | Amphib Assault Vehicles | | 134 | | | | | | | | | | | | | | |
| | No of vehicles | 1773 | 2577 | 2055 | 330 | 2114 | 357 | 103.25 m | 39.08 m | 33.02 m | 342.5 mt | 299.8 m2 | 817.4 m3 | 14375 kg/m2 | #DIV/0! | #DIV/0! | 5215.0 mt |

## 20.1.21 Vehicle List by Battalion

**Marine Divisions**

**Infantry Regiment/Battalion**

Infantry Battalion, H&S Company

| TAM # | ITEM | Quantity | Length(in) | Width (in) | Height (in) | Weigth (lbs) |
|---|---|---|---|---|---|---|
| D1002 | Truck, ambulance, two litter, 1/4 ton, HMMWV, M1035 | 7 | 183 | 86 | 72 | 6100 |
| D1016 | Truck, cargo, 1 1/4 ton, diesel, 4x4, M1008 | 15 | 217 | 80 | 76 | 8600 |
| D1158 | Truck, utility, cargo troop carrier, 1 1/4 ton, M998 | 93 | 191 | 86 | 72 | 5900 |
| D1159 | Truck, utility, armanent carrier, M1043 | 30 | 190.5 | 86 | 74 | 7258 |

**Artillery Regiment**

| Headquarters Battery Regiment and Battalion, 155 M198 Battery | | Quantity | Length(in) | Width (in) | Height (in) | Weigth (lbs) |
|---|---|---|---|---|---|---|
| TAM # | ITEM | Headquarters Battery, Regiment | | | | |
| B2462 | Tractor, medium, full tracked, 82-30 | 6 | 208 | 144 | 132 | 47460 |
| B2464 | Tractor, full tracked, MC-1150E | 4 | 213 | 85 | 93 | 26800 |
| B2566 | Truck, forklift | 11 | 196 | 89 | 79 | 11080 |
| D0230 | Semitrailer, low bed, 40 ton, M870A1 | 3 | | | | |
| D0860 | Trailer, cargo, 1 1/2, M105A2 | 35 | 167 | 83 | 53 | 2800 |
| D1059 | Truck, cargo, 5 ton, M923 | 83 | 327 | 115 | 116 | 22600 |
| D1158 | Truck, utility, 1 1/4 ton, M998 | 68 | 191 | 86 | 72 | 5900 |
| D1212 | Truck, wrecker, 5 ton, M936 | 4 | 362 | 121 | 120 | 38155 |
| E0665 | Howitzer, med, towed, 155mm, M198 | 6 | 296 | 111 | 86 | 15800 |

**Tank Battalion**

| TAM # | ITEM | Quantity | Length(in) | Width (in) | Height (in) | Weigth (lbs) |
|---|---|---|---|---|---|---|
| B2561 | Truck, forklift | 1 | 315 | 102 | 101 | 25600 |
| D0860 | Trailer, cargo, 1 1/2 ton, M105A2 | 21 | 167 | 83 | 53 | 2800 |
| D0875 | Trailer, flatbed, 22 1/2 ton, M14 | 8 | | | | |
| D0880 | Trailer, tank, water, 400 gal, M149A1 | 9 | 161 | 90 | 77 | 2600 |
| D1002 | Truck, ambulance, 1 1/4 ton, HMMWV, M1035 | 9 | 183 | 86 | 72 | 6100 |
| D1059 | Truck, cargo, 5 ton, M923 | 38 | 327 | 115 | 116 | 22600 |
| D1125 | Truck, TOW carrier with equipment, HMMWV, M1045 | 26 | 185 | 85 | 73 | 7178 |
| D1158 | Truck, utility, 1 1/4 ton, M998 | 52 | 191 | 86 | 72 | 5900 |
| D1212 | Truck, wrecker, M936 | 2 | 362 | 121 | 120 | 38155 |
| E1377 | Recovery vehicle, full tracked, M88A2 | 12 | 323 | 144 | 124 | 200 |
| E1888 | Tank, combat, FT, 120mm gun M1A1 | 58 | 387 | 144 | 217 | 123780 |

**Assault Amphibian Battalion**

| TAM # | ITEM | Quantity | Length(in) | Width (in) | Height (in) | Weigth (lbs) |
|---|---|---|---|---|---|---|
| D0860 | Trailer, cargo, 1 1/2 ton, M105A2 | 3 | 167 | 83 | 53 | 2800 |
| D0876 | Trailer, powered, 22 1/2 ton, M14 | 6 | 260 | 96 | 62 | 16000 |
| D0880 | Trailer, tank, water, 400 gal, M149A1 | 11 | 161 | 90 | 77 | 2600 |
| D1059 | Truck, cargo, 5 ton, M923A1 | 22 | 327 | 115 | 116 | 22600 |
| D1158 | Truck, utility, 1 1/4 ton, M998 | 26 | 191 | 86 | 72 | 5900 |
| D1212 | Truck, wrecker, M936 | 1 | 362 | 121 | 120 | 38155 |
| E0796 | AAV, AAVC7A1 | 14 | 311 | 126 | 176 | 47300 |
| E0846 | AAV, AAVP7A1 | 213 | 317 | 147 | 178 | 46360 |
| E0856 | AAV, AAVR7A1 | 6 | 311 | 126 | 178 | 50780 |

**Combat Engineer Battalion, Marine Division**

H&S Company

| TAM # | ITEM | Quantity | Length(in) | Width (in) | Height (in) | Weigth (lbs) |
|---|---|---|---|---|---|---|
| D1002 | Truck, ambulance, two litter, M1035 | 1 | 183 | 86 | 72 | 6100 |
| D1158 | Truck, utility, cargo, 1 1/4 ton, M998 | 2 | 191 | 86 | 72 | 5900 |

Engineer Support Company

| TAM # | ITEM | Quantity | Length(in) | Width (in) | Height (in) | Weigth (lbs) |
|---|---|---|---|---|---|---|
| B0395 | Compressor, Air, 250 CFM, Trailer-Mounted w/Pneumatic | 5 | 214 | 97 | 83 | 9000 |
| B0399 | Crane, Rough Terrain, Hydraulic, 30 ton | 4 | | | | |
| B0589 | Excavator, Combat, M9 Armored Combat Earthmover (ACE) | 16 | 246 | 126 | 105 | 35500 |
| B0590 | Excavator, Hydraulic, Multipurpose Wheel | 1 | | | | |
| B1082 | Grader, Road, Motorized | 6 | 327 | 95 | 127 | 31400 |
| B1326 | Mixer, Concrete, Trailer-mounted | 1 | 112 | 98 | 102 | 5600 |
| B1785 | Roller, Compactor, Vibratory | 2 | 207 | 104 | 131 | 23800 |
| B1922 | Scraper-Tractor, Wheeled | 2 | 501 | 140 | 140 | 64950 |
| B2444 | Tractor, Full-Tracked, Small, w/Bullgrader | 5 | | | | |
| B2460 | Tractor, Full-Tracked, Small, w/Angled blade | 18 | 191 | 110 | 116 | 25200 |

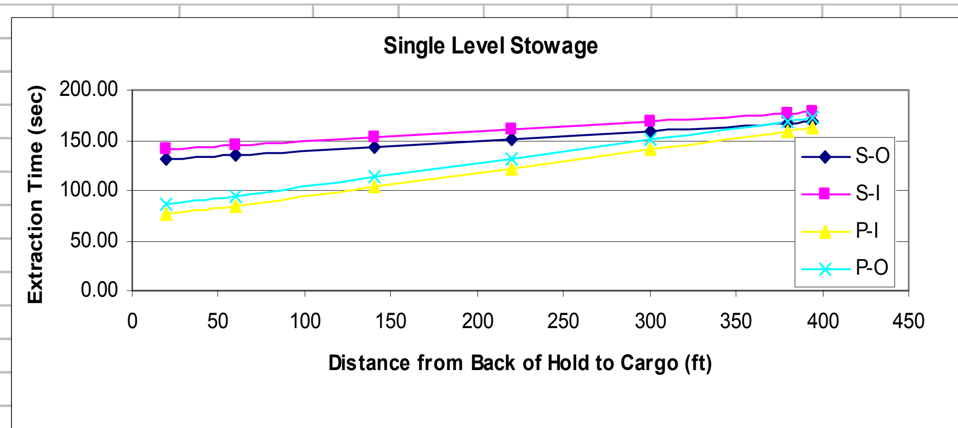
## 20.1.22 Vehicle List and Dimensions

| | TAM # | Description | Quantity | length_in | width_in | height_in | weight_lb |
|---|---|---|---|---|---|---|---|
| 1 | A2151 | Radio set, vehicle (PLRS) | 6 | | | | |
| 2 | B0391 | Container handler, RT | 11 | 423 | 140 | 176 | 103800 |
| 3 | B0395 | Compressor, Air, 250 CFM, Trailer-Mounted w/Pneumatic | 5 | 214 | 97 | 83 | 9000 |
| 4 | B0399 | Crane, Rough Terrain, Hydraulic, 30 ton | 4 | | | | |
| 5 | B0443 | Crane, high speed | 1 | 500 | 102 | 139 | 70380 |
| 6 | B0446 | Crane, rough terrain, hydraulic, light | 4 | 324 | 96 | 102 | 26000 |
| 7 | B0471 | Demolition equipment, engineer squad | 9 | 35 | 20 | 14 | 200 |
| 8 | B0589 | Excavator, combat M9 ACE | 5 | 246 | 126 | 105 | 35500 |
| 9 | B0590 | Excavator, Hydraulic, Multipurpose Wheel | 1 | | | | |
| 10 | B1082 | Grader, Road, Motorized | 6 | 327 | 95 | 127 | 31400 |
| 11 | B1326 | Mixer, Concrete, Trailer-mounted | 1 | 112 | 98 | 102 | 5600 |
| 12 | B1785 | Roller, compactor, vibrator | 4 | 207 | 104 | 131 | 23800 |
| 13 | B1922 | Scraper, tractor, wheeled, 621 B | 6 | 501 | 140 | 140 | 64950 |
| 14 | B2444 | Tractor, Full-Tracked, Small, w/Bullgrader | 5 | | | | |
| 15 | B2460 | Tractor, full tracked, blade, 1150E | 6 | 191 | 110 | 116 | 25200 |
| 16 | B2462 | Tractor, medium, full tracked, 82-30 | 6 | 208 | 144 | 132 | 47460 |
| 17 | B2464 | Tractor, full tracked, MC-1150E | 4 | 213 | 85 | 93 | 26800 |
| 18 | B2465 | Tractor, Rubber Tired, Articulate Steering | 10 | | | | |
| 19 | B2467 | Tractor, RT, Wheeled, Industrial | 5 | | | | |
| 20 | B2482 | Tractor, All Wheeled Drive, w/Attachments | 15 | 250 | 96 | 102 | 16000 |
| 21 | B2560 | Truck, Forklift | 8 | | | | |
| 22 | B2561 | Truck, forklift | 1 | 315 | 102 | 101 | 25600 |
| 23 | B2565 | Truck, Forklift, Rough Terrain | 5 | | | | |
| 24 | B2566 | Trk, forklift, RT, 4000lb | 2 | 196 | 89 | 79 | 11080 |
| 25 | B2567 | Tractor, 644E | 1 | 308 | 105 | 132 | 35465 |
| 26 | B2685 | Welding machine, arc, trailer mounted | 4 | 187 | 96 | 85 | 6800 |
| 27 | D0080 | Chassis, trailer, general purpose, 3 1/2 ton, M353 | 32 | 187 | 96 | 48 | 2800 |
| 28 | D0085 | Trailer, 3/4 ton, two wheel, M116A3 | 25 | 147 | 85 | 35 | 1340 |
| 29 | D0090 | Cleaner, Steam Pressure Jet, Trailer Mounted | 2 | 85 | 58 | 57 | 1200 |
| 30 | D0201 | Motorcycle, military, M1030 | 2 | 87 | 36 | 48 | 260 |
| 31 | D0209 | Logistics Vehicle System (LVS), MK48 FPU | 3 | 239 | 96 | 102 | 25400 |
| 32 | D0215 | Semitrailer, fueler, 5,000 gal, M970 | 20 | 368 | 96 | 105 | 16200 |
| 33 | D0230 | Semitrailer, low bed, 40 ton, M870A1 | 3 | | | | |
| 34 | D0235 | Semitrailer, low bed, 40 ton, M870 | 2 | 560 | 120 | 69 | 20000 |
| 35 | D0250 | Semitrailer, stake, 6 ton, two wheel, M118A1 | 17 | 281 | 96 | 102 | 6230 |
| 36 | D0850 | Trailer, cargo, 3/4 ton, M101 | 21 | 147 | 74 | 35 | 1340 |
| 37 | D0860 | Trailer, cargo, 1 1/2 ton, M105 | 10 | 167 | 83 | 53 | 2800 |
| 38 | D0875 | Trailer, flatbed, 22 1/2 ton, M14 | 8 | | | | |
| 39 | D0876 | Trailer, powered, 22 1/2 ton, container hauler, MK14 | 171 | 260 | 96 | 62 | 16000 |
| 40 | D0877 | Trailer, powered, wrecker/recovery, MK15 | 3 | 248 | 961 | 138 | 28400 |
| 41 | D0878 | Trailer, powered, fifth wheel, 4x4, MK16, MOD O | 2 | 202 | 96 | 87 | 16200 |
| 42 | D0879 | Trailer, powered, 20 ton, MK17 | 41 | 260 | 96 | 94 | 22000 |
| 43 | D0880 | Trailer, tank, water 400 gal, M149A2 | 40 | 161 | 90 | 77 | 2600 |
| 44 | D0881 | Trailer, ribbon bridge, MK18 | 81 | 305 | 96 | 75 | 20000 |
| 45 | D1001 | Truck, ambul, M997 | 16 | 205 | 86 | 102 | 7800 |
| 46 | D1002 | Ambulance, 1 1/4 ton, HMMWV | 2 | 183 | 86 | 72 | 6100 |
| 47 | D1016 | Truck, cargo, 1 1/4 ton, diesel, 4x4, M1008 | 15 | 217 | 80 | 76 | 8600 |
| 48 | D1059 | Truck, 5 ton, M923 | 20 | 327 | 115 | 116 | 22600 |
| 49 | D1061 | Truck, 5 ton, XLWB, with winch, M928 | 3 | 386 | 121 | 121 | 25200 |
| 50 | D1072 | Truck, dump, 5 ton, 6x6, M927 | 14 | 289 | 128 | 121 | 24800 |
| 51 | D1082 | Truck, firefighting, 1 1/4 ton, 4x4, M1028 | 6 | 220 | 81 | 83 | 8400 |
| 52 | D1110 | Truck, Tank, Fuel Serv, 1,200-gal | 2 | | | | |
| 53 | D1125 | Truck, TOW carrier with equipment, HMMWV, M1045 | 26 | 185 | 85 | 73 | 7178 |
| 54 | D1134 | Truck, Tractor | 3 | 265 | 121 | 121 | 21140 |
| 55 | D1140 | Truck, Tractor, 10-ton, 6x6, w/WN | 3 | | | | |
| 56 | D1158 | HMMWV, 1 1/4 ton, M1008 | 23 | 191 | 86 | 72 | 5900 |
| 57 | D1159 | Truck, utility, armanent carrier, M1043 | 30 | 190.5 | 86 | 74 | 7258 |
| 57 | D1212 | Truck, wrecker, 5 ton, M936 | 4 | 362 | 121 | 120 | 38155 |
| 58 | E0665 | Howitzer, med, towed, 155mm, M198 | 6 | 296 | 111 | 86 | 15800 |
| 59 | E0796 | AAV, AAVC7A1 | 14 | 311 | 126 | 176 | 47300 |
| 60 | E0846 | AAV, AAVP7A1 | 213 | 317 | 147 | 178 | 46360 |
| 61 | E0856 | AAV, AAVR7A1 | 6 | 311 | 126 | 178 | 50780 |
| 62 | E0942 | LAV, antitank | 16 | 251 | 99 | 123 | 25000 |
| 63 | E0946 | LAV, command and control | 10 | 254 | 99 | 105 | 26180 |
| 64 | E0947 | LAV, light assault-25 | 60 | 252 | 99 | 106 | 24200 |
| 65 | E0948 | LAV, logistic | 16 | 255 | 98 | 109 | 28200 |
| 66 | E0949 | LAV, mortar | 8 | 255 | 99 | 95 | 23300 |
| 67 | E0950 | LAV, maintenance/recovery | 6 | 291 | 99 | 112 | 28400 |
| 68 | E1377 | Recovery vehicle, full tracked, M88A2 | 12 | 323 | 144 | 124 | 200 |
| 69 | E1888 | Tank, combat, FT, 120mm gun M1A1 | 58 | 387 | 144 | 217 | 123780 |
| 70 | W0110 | Dolly trailer, converter, 6 ton, M197A1 | 96 | | | | |

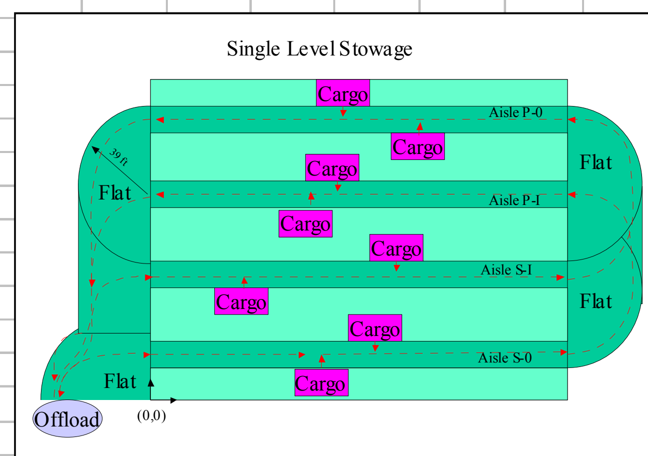
## Annex U - Excel Model to determine Extraction Times

20.1.23 An Excel spreadsheet was used to model each of the alternative deck and cargo arrangements to quantitatively assess the extraction times. Please note the model is only suitable for single vehicle extractions.

| Hold Dimensions | Aisle S-O |
|---|---|
| - length (ft) | 414 |
| - aisle width (ft) | 14 |
| **Offload point location** | |
| - longitudinal (ft) | -65.7 |
| - transverse (ft) | 0 |
| **Cargo location** | |
| - longitudinal (ft) | 200 |
| Time to extract cargo from stowed position (sec) | 30 |
| Horizontal transfer speed (fps) | 15 |
| Speed in turn (fps) | 7.5 |
| Turn Radius (ft) | 39 |
| Human horizontal speed (fps) | 6 |
| Human vertical speed (fps) | 3 |




| | Aisle S-O Time (sec) | Aisle S-I Time (sec) | Aisle P-I Time (sec) | Aisle P-O Time (sec) |
|---|---|---|---|---|
| Operator moves to stowed location | 48 | 55 | 62 | 69 |
| Remove from stowed position | 30 | 30 | 30 | 30 |
| Transport from stowed position to front of hold | 14 | 14 | | |
| Turn on Deck 1 | 17 | 17 | | |
| Transfer on deck 1 to back of hold | 28 | 28 | 13 | 13 |
| Turn on backdeck | 8 | 8 | 8 | 8 |
| Transfer to offload site | 4 | 7 | 4 | 7 |
| **Total (sec)** | **149** | **159** | **118** | **127** |

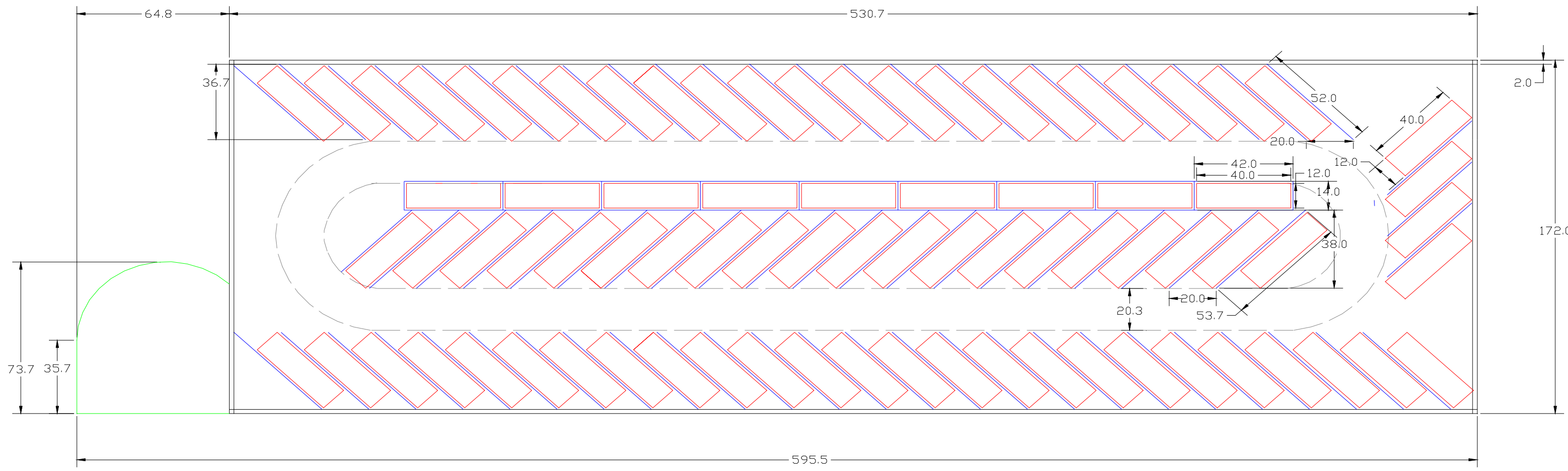


## Annex V - AutoCAD cargo deck arrangements (#1-11)

20.1.24 Drawings No.1 through 11 are attached.


Single Deck
80 Large Trucks (12'x40')
Cargo Dimensions- 172'X414'
Cargo/Loading Dimensions-172'x518.6'
Cargo Area=71208sqft
Deck Area=10,898sqft
Total Cargo/Deck Area=82,106sqft
Stowage Factor= 47%

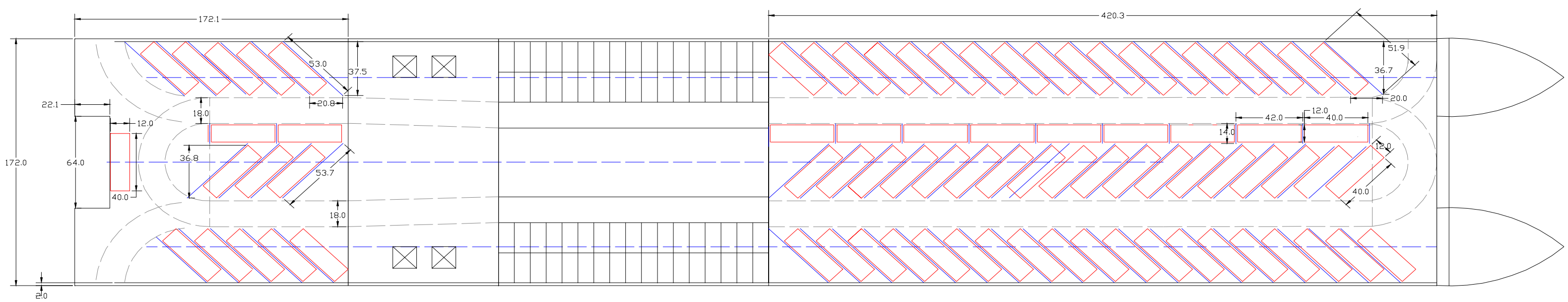
| | |
|---|---|
| Alternate Arrangement:Single Level Palletized Layout | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 1 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/09/03 |




Large Trucks — Driving Lanes
Parking Lines — Flat Deck

Single Deck-Arrangement
80 Vehicles
Vehicle Area=12'x40'=38400sqft
Cargo Dimensions=172'x530.7'
Cargo+Deck Dimensions=172'x595.5'
Cargo Area=91,280.4sqft
Deck Area=4,363.6sqft
Total Cargo/Deck Area=95,644sqft
Stowage Factor=40.2%

| | |
|---|---|
| Alternate Arrangement: Single Level Angled Layout | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 2 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/09/03 |




Single Level
Angle Parking- As Applied to a Ship Design
Cargo Area=100,477.6sqft
80 Vehicles=12'x40'=38400sqft
Stowage Factor=38.2%

| | |
|---|---|
| Large Trucks | Driving Lanes |
| Parking Lines | Flat Deck |

| | |
|---|---|
| Alternate Arrangement: Single Level Angled Parking Applied to a Ship Design | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 3 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/09/03 |


Elevator-Deck 1
28 Large Vehicle
Vehicle Area=13,440sqft
Cargo Area=91'x455'
Deck Area=91'x554.3'
Stowage Factor=28.4%

Elevator- Deck 2
28 Large Vehicles
Vehicle Area=13,440sqft
Cargo Area=91'x455'
Stowage Factor=32.5%

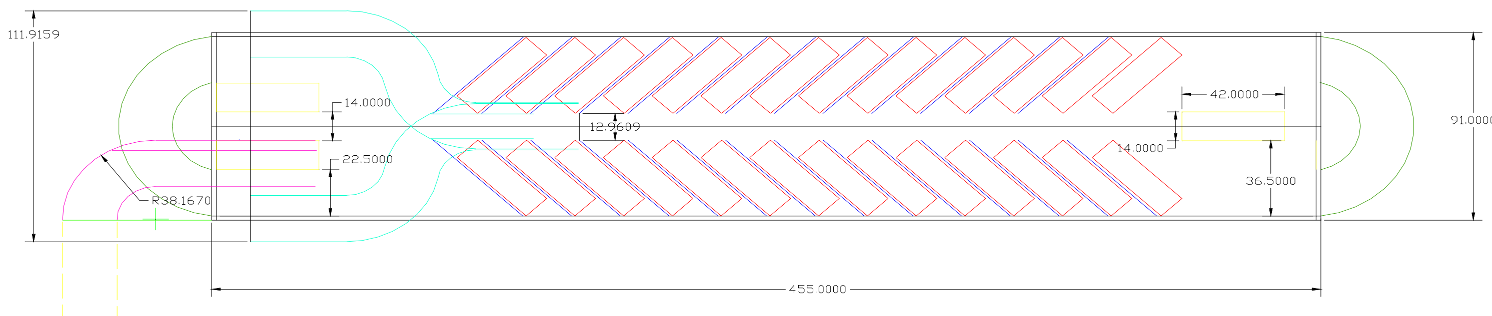
Elevator- Deck 3
28 Large Vehicles
Vehicle Area=13,440sqft
Cargo Area=91'x455'
Stowage Factor=32.5%

Elevator- 3 Decks
84 Large Vehicles
Total Vehicle Area=40,320sqft
Total Cargo Area=124,215sqft
Total Deck Area=5,874sqft
Cargo/Deck Area=130,089sqft

| | |
|---|---|
| Large Trucks | Elevators |
| Parking Lines | Flat Deck |

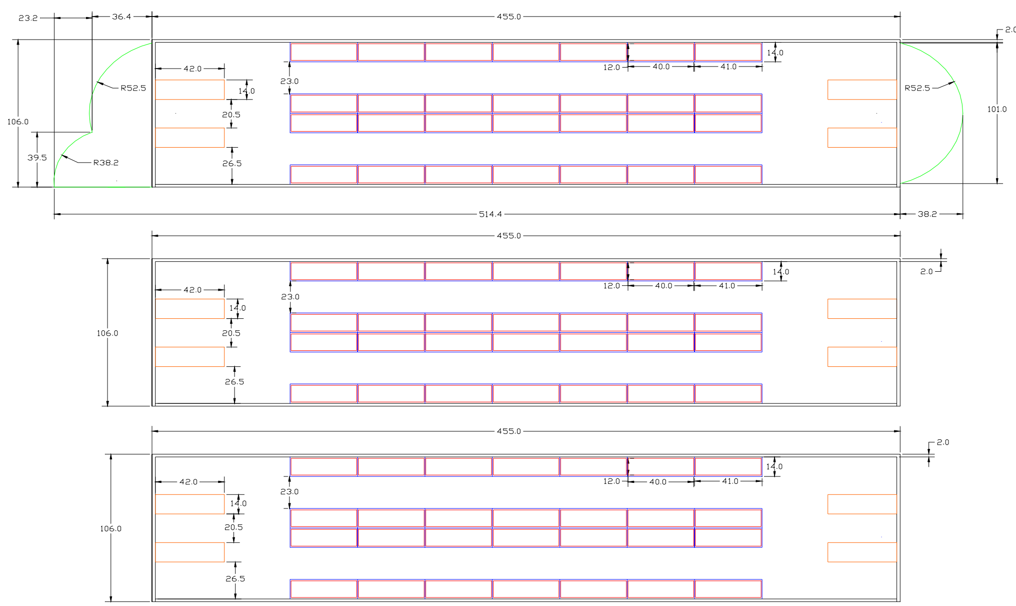
| | |
|---|---|
| Alternate Arrangement: Elevator-Palletized-91' Beam | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 4 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/09/03 |

The 91' beam which was most efficient for palletized parking- will not work for angled parking. The lanes are not large enough, and the s-curves require more space than beam will allow. Must use at least a 106' beam for angled parking.




Large Trucks
Parking Lines
Elevators
Flat Deck
Turning Radius
90 Degree Turn
S-curves

| | |
|---|---|
| Alternate Arrangement: 91' Beam-Angled Layout-2 Elevators | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 5 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/09/03 |




Elevator-Deck 1
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x455'
Deck Area= 106'x514.4
Stowage Factor=24.5%

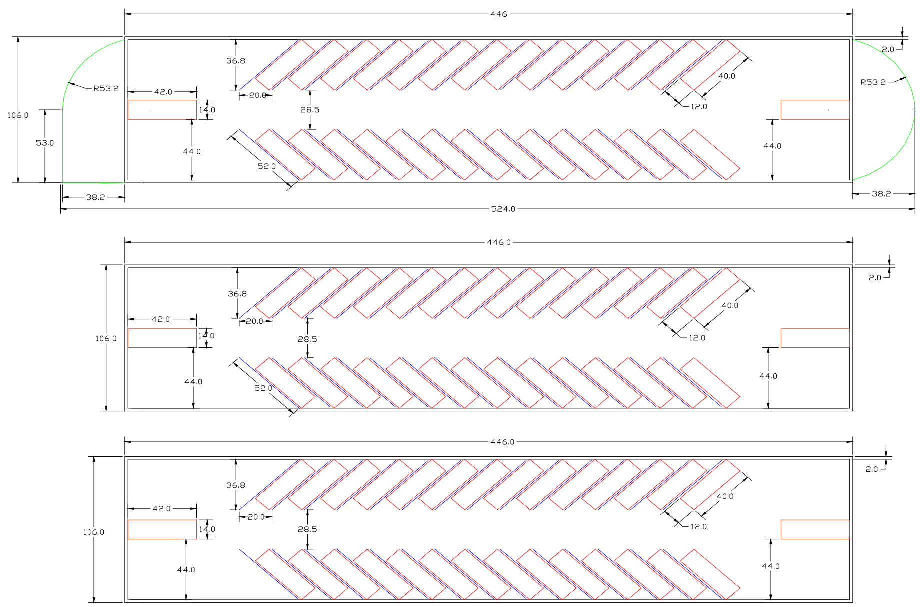
Elevator- Deck 2
28 Large Vehicles
Vehicle Area=12'x40'=13,440sqft
Cargo Area= 106'x455'
Stowage Factor=27.9%

Elevator- Deck 3
28 Large Vehicles
Vehicle Area=12'x40'=13,440sqft
Cargo Area= 106'x455'
Stowage Factor=27.9%

Large Trucks
Parking Lines
Elevators
Flat Deck

Elevator- 3 Decks-Palletized
84 Large Vehicles
Vehicle Area=40,320sqft
Total Cargo Area=14,4690sqft
Total Deck Area=6,579.7sqft
Cargo/Deck Area=151,269.7sqft

| | |
|---|---|
| Alternate Arrangement: Elevator- Palletized 106' Beam | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 6 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/09/03 |



Elevator-Deck 1
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x446'
Deck Area= 106'x522.7'
Stowage Factor=25.2%

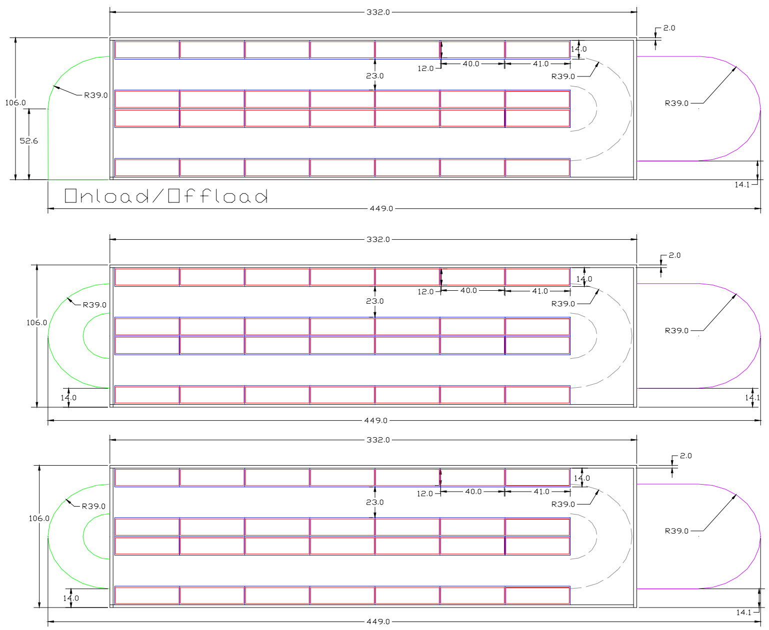
Elevator- Deck 2
28 Large Vehicles
Vehicle Area=12'x40'=13,440sqft
Cargo Area= 106'x446'
Stowage Factor=28.4%

Elevator- Deck 3
28 Large Vehicles
Vehicle Area=12'x40'=13,440sqft
Cargo Area= 106'x446'
Stowage Factor=28.4%

Large Trucks
Parking Lines
Elevators
Flat Deck

Elevator- 3 Decks
84 Large Vehicles
Vehicle Area=40,320sqft
Total Cargo Area=141,828sqft
Total Deck Area=6,167.8sqft
Cargo/Deck Area=147,996sqft

| | |
|---|---|
| Alternate Arrangement: Elevator- Angled-106' Beam | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 7 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/09/03 |




1 Full Spiral Ramp- Deck 1
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x332'
Deck Area= 106'x449'
Stowage Factor=30.6%

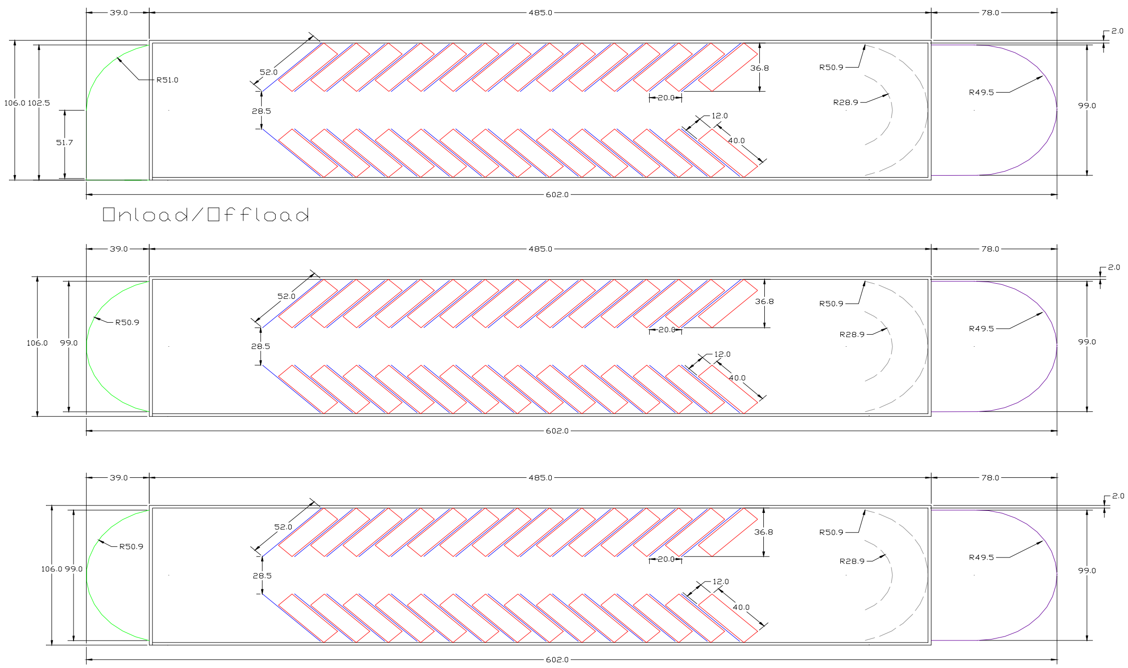
1 Full Spiral Ramp- Deck 2
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x332'
Deck Area= 106'x449'
Stowage Factor=31.3%

1 Full Spiral Ramp- Deck 3
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x332'
Deck Area= 106'x449'
Stowage Factor=31.3%

Large Trucks
Parking Lines
Turning Lanes
Spiral Ramp
Flat Deck

1 Full Spiral Ramp-3 Decks
84 Large Vehicles
Vehicle Area=40,320sqft
Total Cargo Area=105,576sqft
Total Deck Area=80,88sqft
Total Spiral Area=16,188sqft
Cargo/Deck/Spiral Area=129,852.4sqft

| | |
|---|---|
| Alternate Arrangement: 1 Full Spiral Ramp: Palletized Layout | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 8 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/09/03 |




1 Full Spiral Ramp
Deck 1-Angled
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x485'
Deck Area= 106'x602'
Stowage Factor=22%

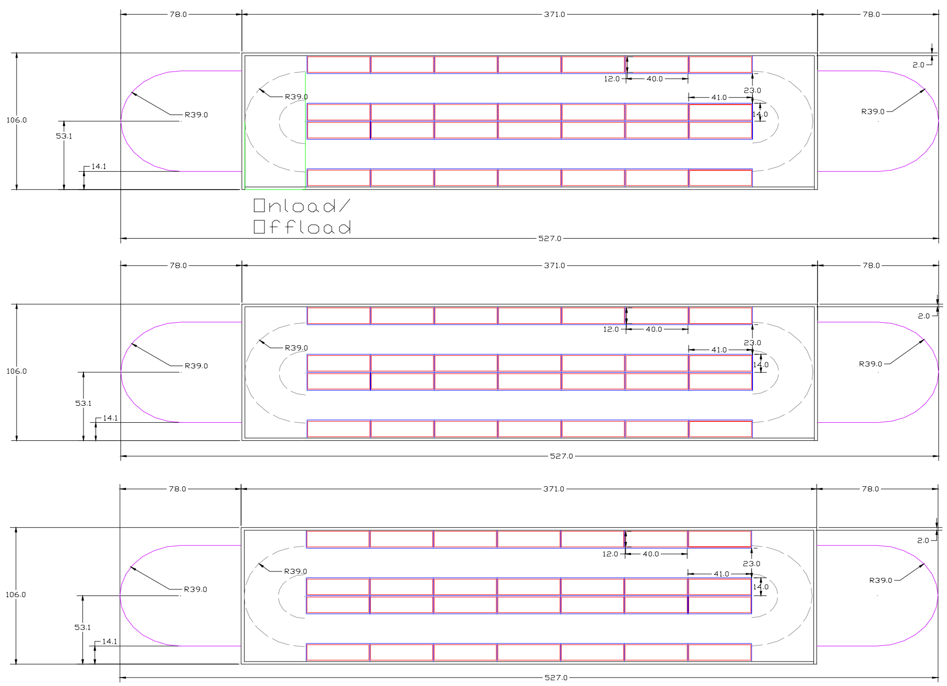
1 Full Spiral Ramp
Deck 2-Angled
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x485'
Deck Area= 106'x602'
Stowage Factor=22.1%

1 Full Spiral Ramp
Deck 3-Angled
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x485'
Deck Area= 106'x602'
Stowage Factor=22.1%

Large Trucks
Parking Lines
Turning Lanes
Spiral Ramp
Flat Deck

1 Full Spiral Ramp-3 Decks-Angled Design
84 Large Vehicles
Vehicle Area=40,320sqft
Total Cargo Area=154,230sqft
Total Deck Area=9.060sqft
Total Spiral Ramp=19,437sqft
Cargo/Deck/Spiral Area=182,727sqft

| | |
|---|---|
| Alternate Arrangement: 1 Full Spiral Ramp | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 9 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/05/03 |




2 Full Spiral Ramps/Racetrack- Deck 1
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x371'
Deck Area= 106'x527'
Stowage Factor=26.8%

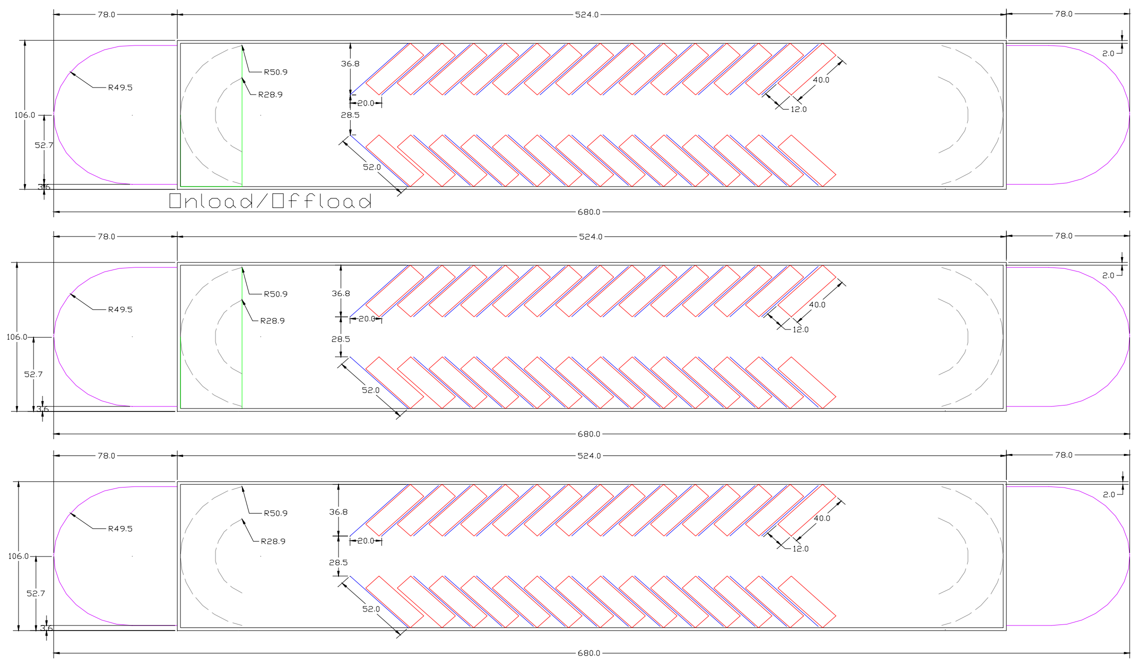
2 Full Spiral Ramps/Racetrack- Deck 1
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x371'
Deck Area= 106'x527'
Stowage Factor=26.8%

2 Full Spiral Ramps/Racetrack- Deck 1
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x371'
Deck Area= 106'x527'
Stowage Factor=26.8%

Large Trucks
Parking Lines
Turning Lanes
Spiral Ramp
Flat Deck

2 Full Spiral Ramps/Racetrack-3 Decks
84 Large Vehicles
Vehicle Area=40,320sqft
Total Cargo Area=117,978sqft
Total Deck Area=Included in Cargo
Total Spiral Area=32,376sqft
Cargo/DeckSpiral Area=150,354sqft

| | |
|---|---|
| Alternate Arrangement: 2 Full Spiral Ramps | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 10 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/05/03 |




2 Full Spiral Ramps/Racetrack
Deck 1- Angled Parking
28 Large Vehicles(12'x40')
Vehicle Area=13,440sqft
Cargo Area=106'x524'
Deck Area= 106'x680'
Stowage Factor=19.6%

2 Full Spiral Ramps/Racetrack
Deck 2- Angled Parking
28 Large Vehicles(12'x40')
Vehicle Area=13,440sqft
Cargo Area=106'x524'
Deck Area= 106'x680'
Stowage Factor=19.6%

2 Full Spiral Ramps/Racetrack
Deck 3- Angled Parking
28 Large Vehicles(12'x40')
Vehicle Area=13,440sqft
Cargo Area=106'x524'
Deck Area= 106'x680'
Stowage Factor=19.6%

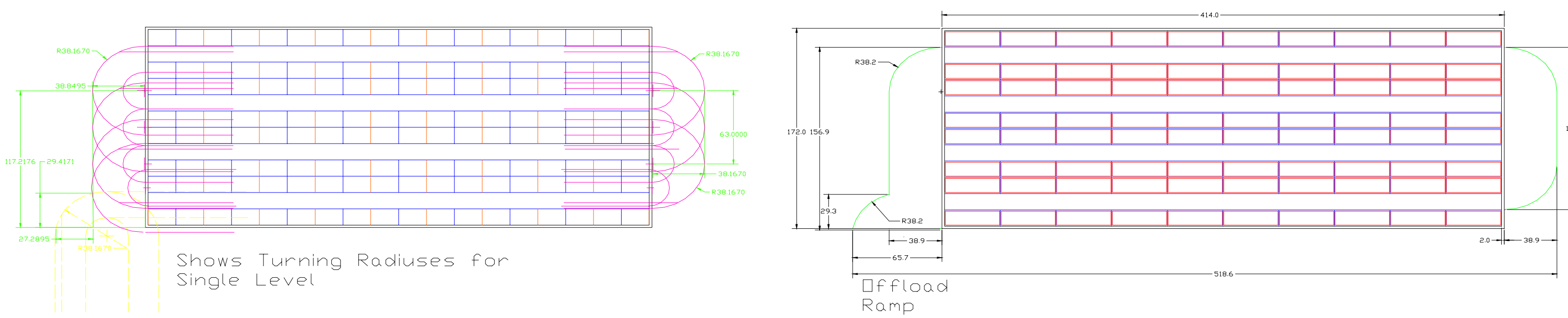
Large Trucks
Parking Lines
Turning Lanes
Spiral Ramp
Flat Deck

2 Full Spiral Ramps/Racetrack
3 Decks-Angled Parking Design
84 Large Vehicles
Vehicle Area=40,320sqft
Total Cargo Area=166,632sqft
Total Deck Area=Included in Cargo
Total Spiral Ramp=38,874sqft
Cargo/Deck/Spiral Area=205,506sqft

| | |
|---|---|
| Alternate Arrangement: 2 Full Spiral Ramps | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 11 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/05/03 |

## Annex W - AutoCAD cargo deck arrangements (#12-22)

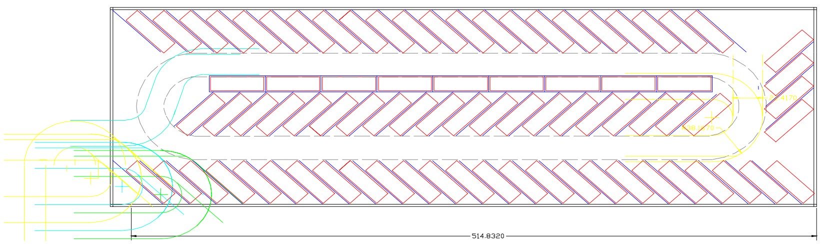
20.1.25 Drawings No.12 through 22 are attached.



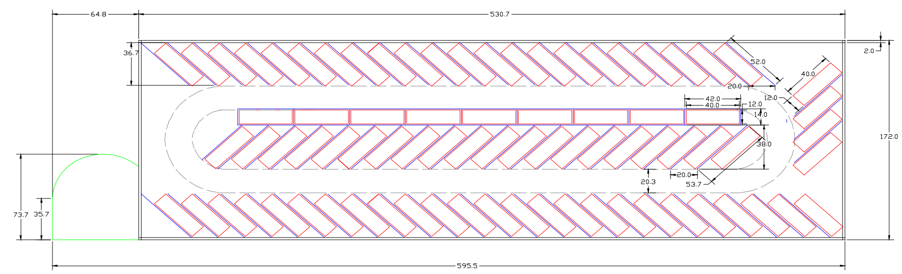

Large Trucks
Parking Lines
Flat Deck

Single Deck
80 Large Trucks (12'x40')
Cargo Dimensions- 172'X414'
Cargo+Loading Dimensions- 172'x518.6'
Cargo Area=71208sqft
Deck Area=10,898sqft
Total Cargo/Deck Area=82,106sqft
Stowage Factor= 47%

| | |
|---|---|
| Alternate Arrangement: Single Level Palletized Layout With Turning Area Required | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 12 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/09/2003 |




Deck Layout Showing Turning Area Required For Vehicles.

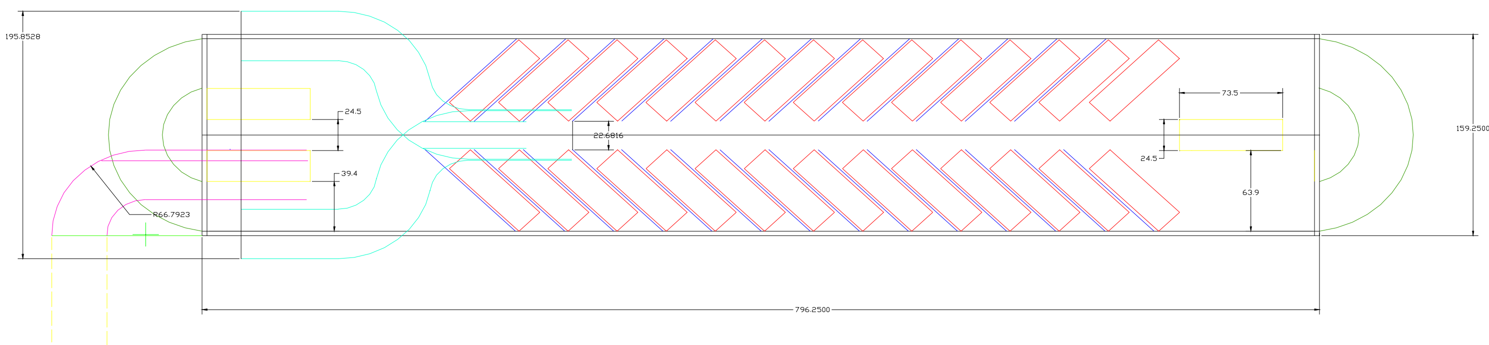



Single Deck-Arrangement: Angled
80 Vehicles
Vehicle Area=12'x40'=38400sqft
Cargo Dimensions=172'x530.7'
Cargo+Deck Dimensions=172'x595.5'
Cargo Area=91,280.4sqft
Deck Area=4,363.6sqft
Total Cargo/Deck Area=95,644sqft
Stowage Factor=40.2%

| | |
|---|---|
| Large Trucks | Driving Lanes |
| Parking Lines | Flat Deck |

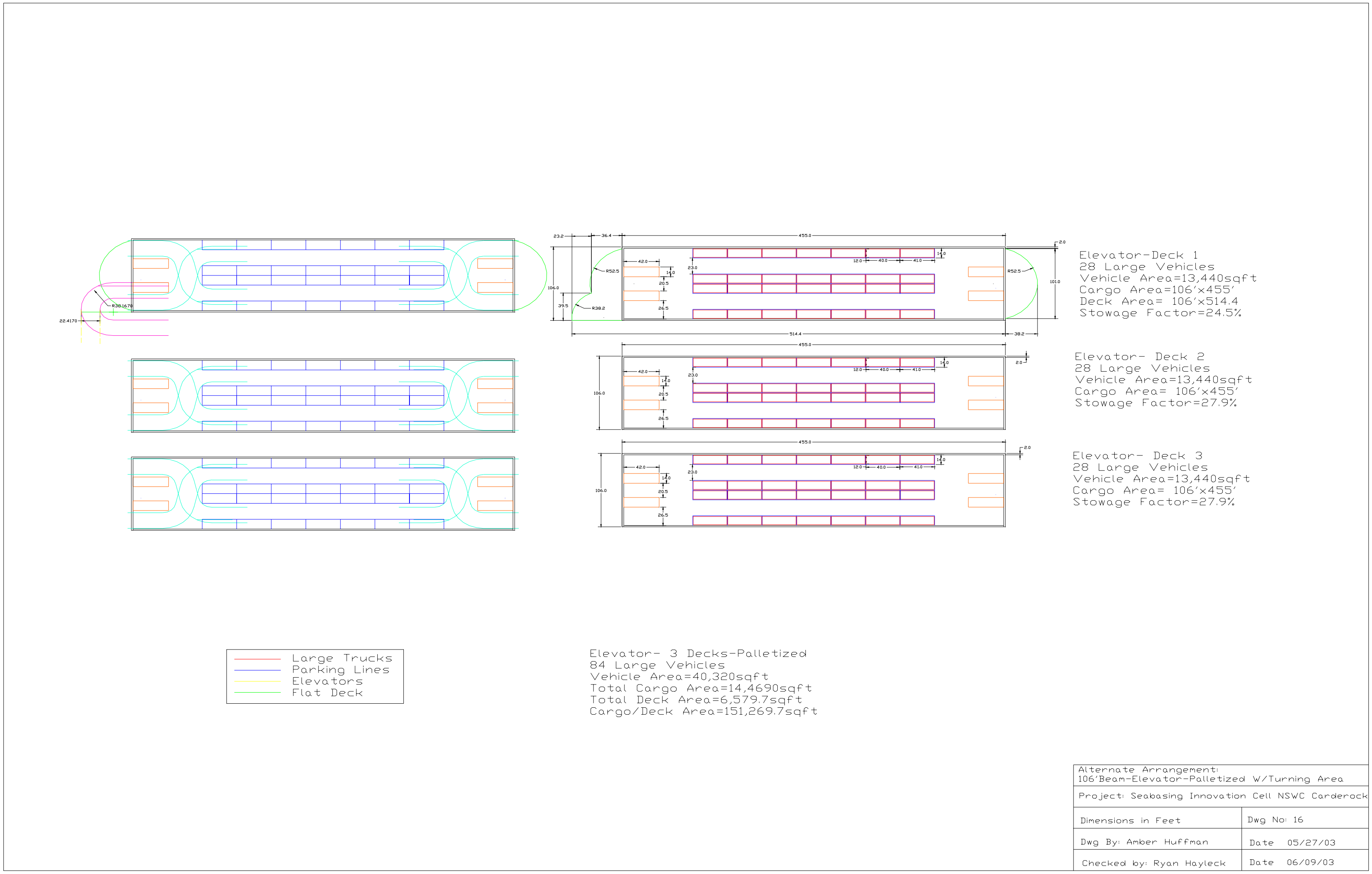
| | |
|---|---|
| Alternate Arrangement: 1 Full Spiral Ramp With Turning Area Required | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 13 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/09/03 |

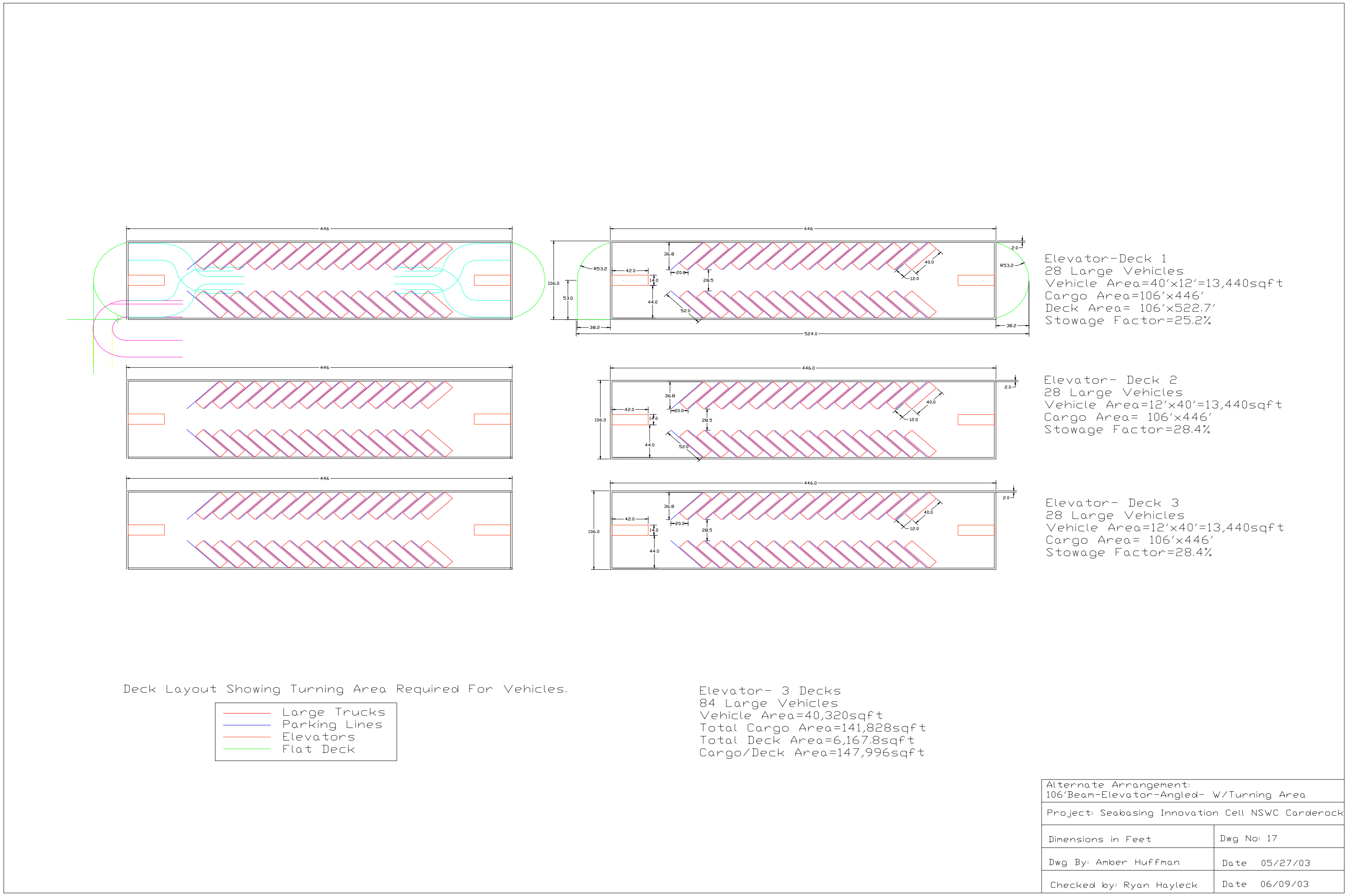
The 91' beam which was most efficient for palletized parking- will not work for angled parking. The lanes are not large enough, and the s-curves require more space than beam will allow. Must use at least a 106' beam for angled parking.

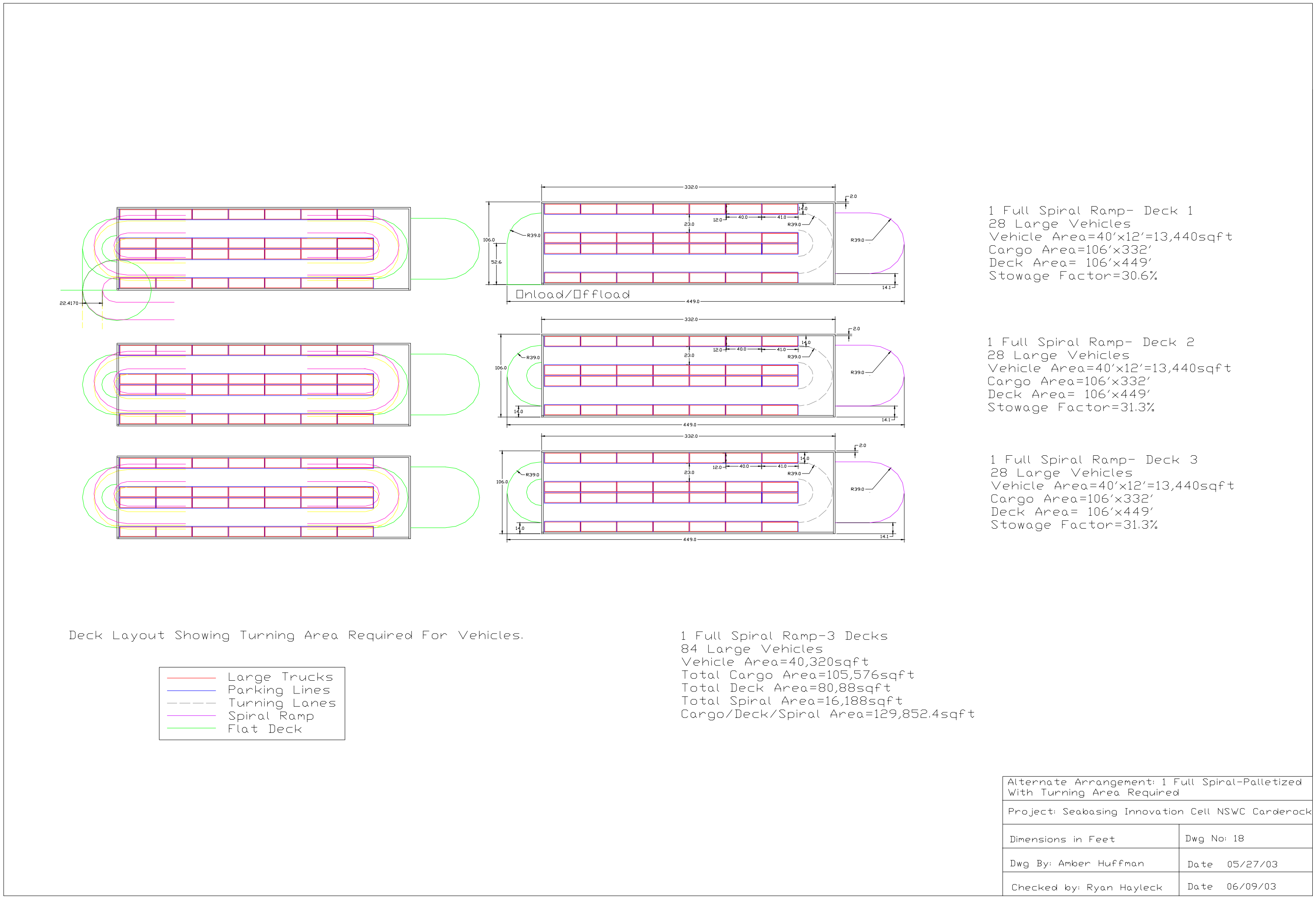


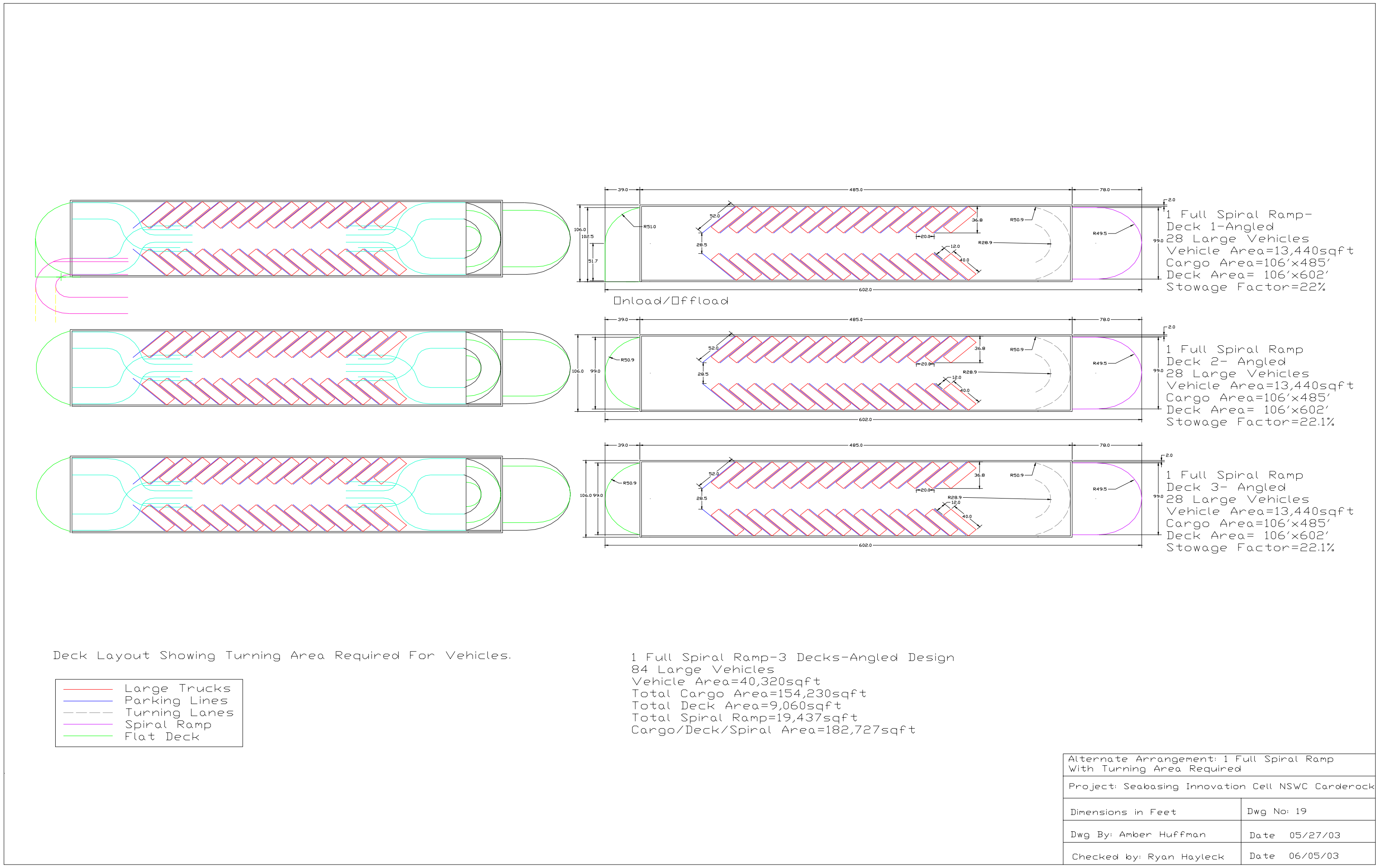

Large Trucks
Parking Lines
Elevators
Flat Deck
Turning Radius
90 Degree Turn
S-curves

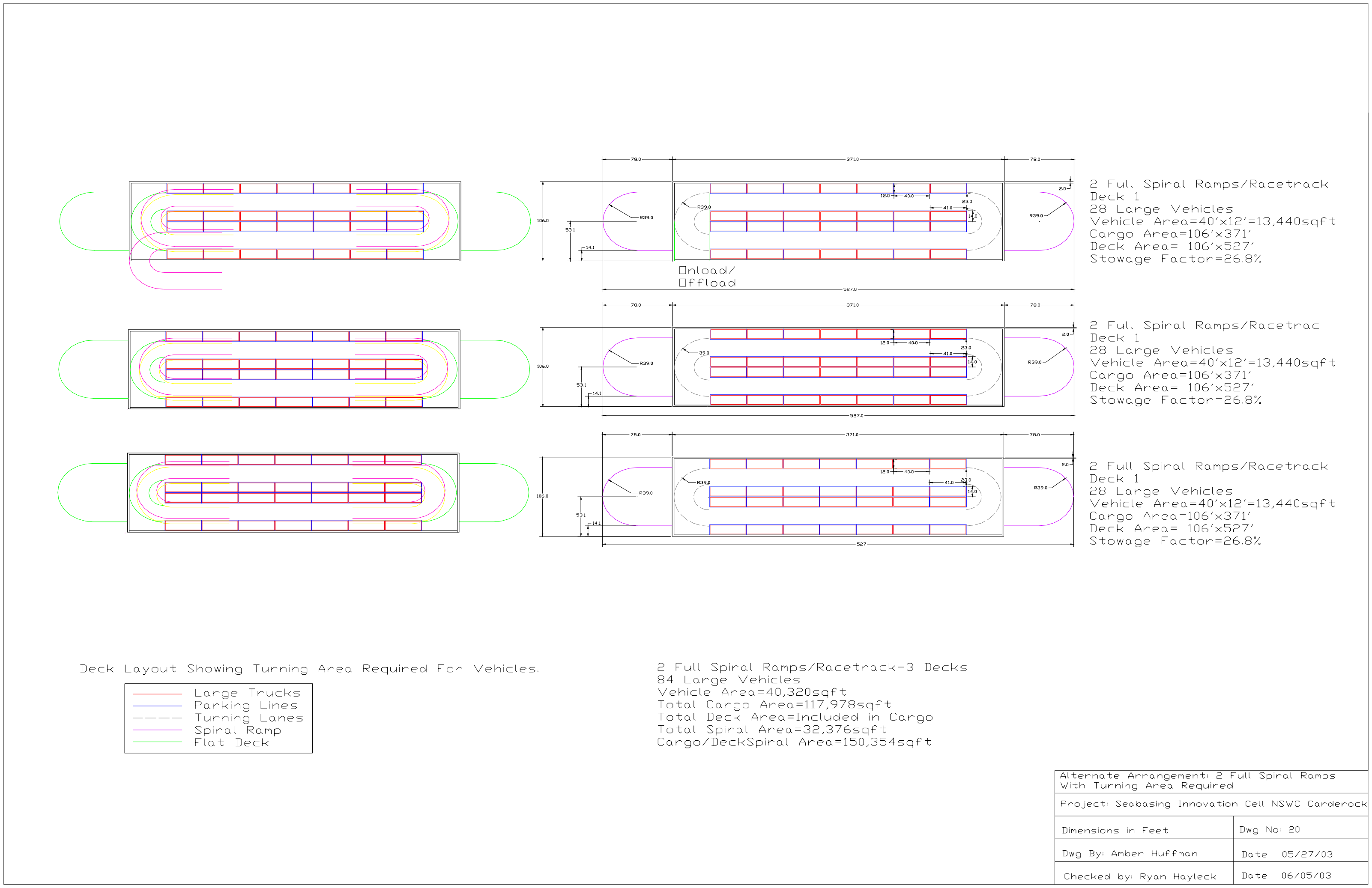
| | |
|---|---|
| Alternate Arrangement: 91' Beam-Angled Layout-2 Elevators | |
| Project: Seabasing Innovation Cell NSWC Carderock | |
| Dimensions in Feet | Dwg No: 15 |
| Dwg By: Amber Huffman | Date 05/27/03 |
| Checked by: Ryan Hayleck | Date 06/09/03 |

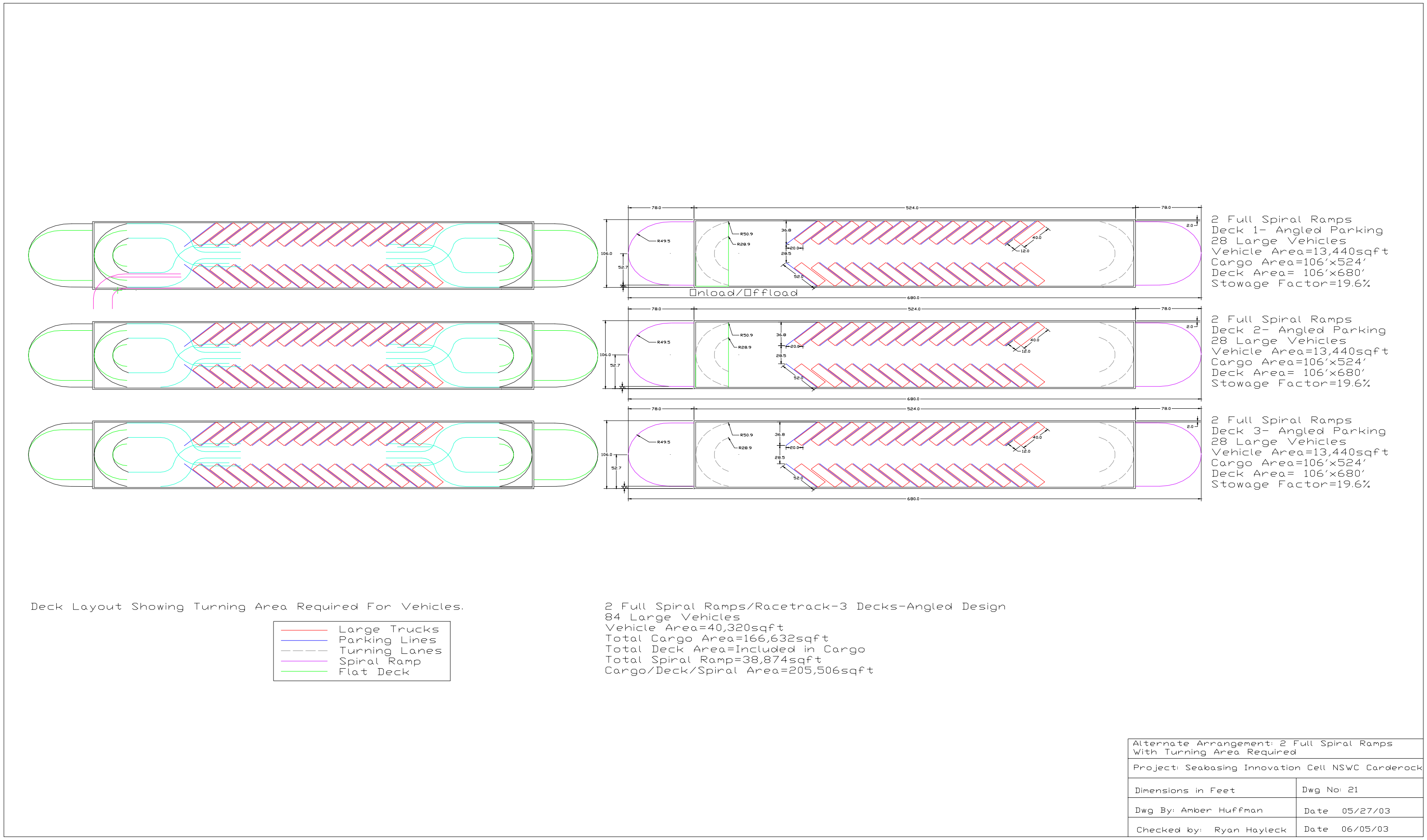

Elevator-Deck 1
28 Large Vehicles
Vehicle Area=13,440sqft
Cargo Area=106'x455'
Deck Area= 106'x514.4
Stowage Factor=24.5%
Elevator- Deck 2
28 Large Vehicles
Vehicle Area=13,440sqft
Cargo Area= 106'x455'
Stowage Factor=27.9%
Elevator- Deck 3
28 Large Vehicles
Vehicle Area=13,440sqft
Cargo Area= 106'x455'
Stowage Factor=27.9%
Large Trucks
Parking Lines
Elevators
Flat Deck
Elevator- 3 Decks-Palletized
84 Large Vehicles
Vehicle Area=40,320sqft
Total Cargo Area=14,4690sqft
Total Deck Area=6,579.7sqft
Cargo/Deck Area=151,269.7sqft
Alternate Arrangement:
106'Beam-Elevator-Palletized W/Turning Area
Project: Seabasing Innovation Cell NSWC Carderock
Dimensions in Feet
Dwg No: 16
Dwg By: Amber Huffman
Date 05/27/03
Checked by: Ryan Hayleck
Date 06/09/03

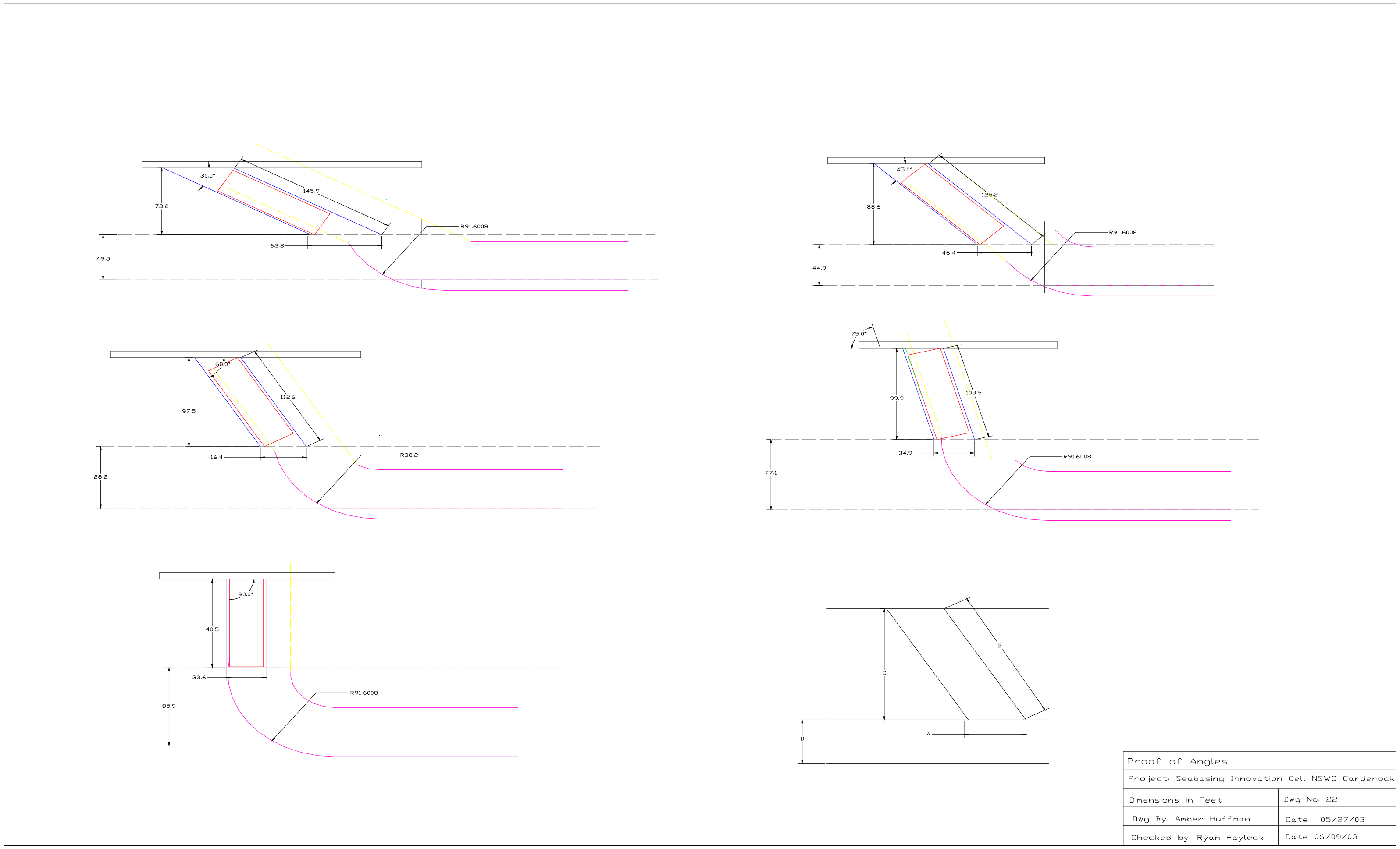

Elevator-Deck 1
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x446'
Deck Area= 106'x522.7'
Stowage Factor=25.2%
Elevator- Deck 2
28 Large Vehicles
Vehicle Area=12'x40'=13,440sqft
Cargo Area= 106'x446'
Stowage Factor=28.4%
Elevator- Deck 3
28 Large Vehicles
Vehicle Area=12'x40'=13,440sqft
Cargo Area= 106'x446'
Stowage Factor=28.4%
Deck Layout Showing Turning Area Required For Vehicles.
Large Trucks
Parking Lines
Elevators
Flat Deck
Elevator- 3 Decks
84 Large Vehicles
Vehicle Area=40,320sqft
Total Cargo Area=141,828sqft
Total Deck Area=6,167.8sqft
Cargo/Deck Area=147,996sqft
Alternate Arrangement:
106'Beam-Elevator-Angled- W/Turning Area
Project: Seabasing Innovation Cell NSWC Carderock
Dimensions in Feet
Dwg No: 17
Dwg By: Amber Huffman
Date 05/27/03
Checked by: Ryan Hayleck
Date 06/09/03


1 Full Spiral Ramp- Deck 1
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x332'
Deck Area= 106'x449'
Stowage Factor=30.6%
1 Full Spiral Ramp- Deck 2
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x332'
Deck Area= 106'x449'
Stowage Factor=31.3%
1 Full Spiral Ramp- Deck 3
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x332'
Deck Area= 106'x449'
Stowage Factor=31.3%
Deck Layout Showing Turning Area Required For Vehicles.
Large Trucks
Parking Lines
Turning Lanes
Spiral Ramp
Flat Deck
1 Full Spiral Ramp-3 Decks
84 Large Vehicles
Vehicle Area=40,320sqft
Total Cargo Area=105,576sqft
Total Deck Area=80,88sqft
Total Spiral Area=16,188sqft
Cargo/Deck/Spiral Area=129,852.4sqft
Alternate Arrangement: 1 Full Spiral-Palletized With Turning Area Required
Project: Seabasing Innovation Cell NSWC Carderock
Dimensions in Feet
Dwg No: 18
Dwg By: Amber Huffman
Date 05/27/03
Checked by: Ryan Hayleck
Date 06/09/03

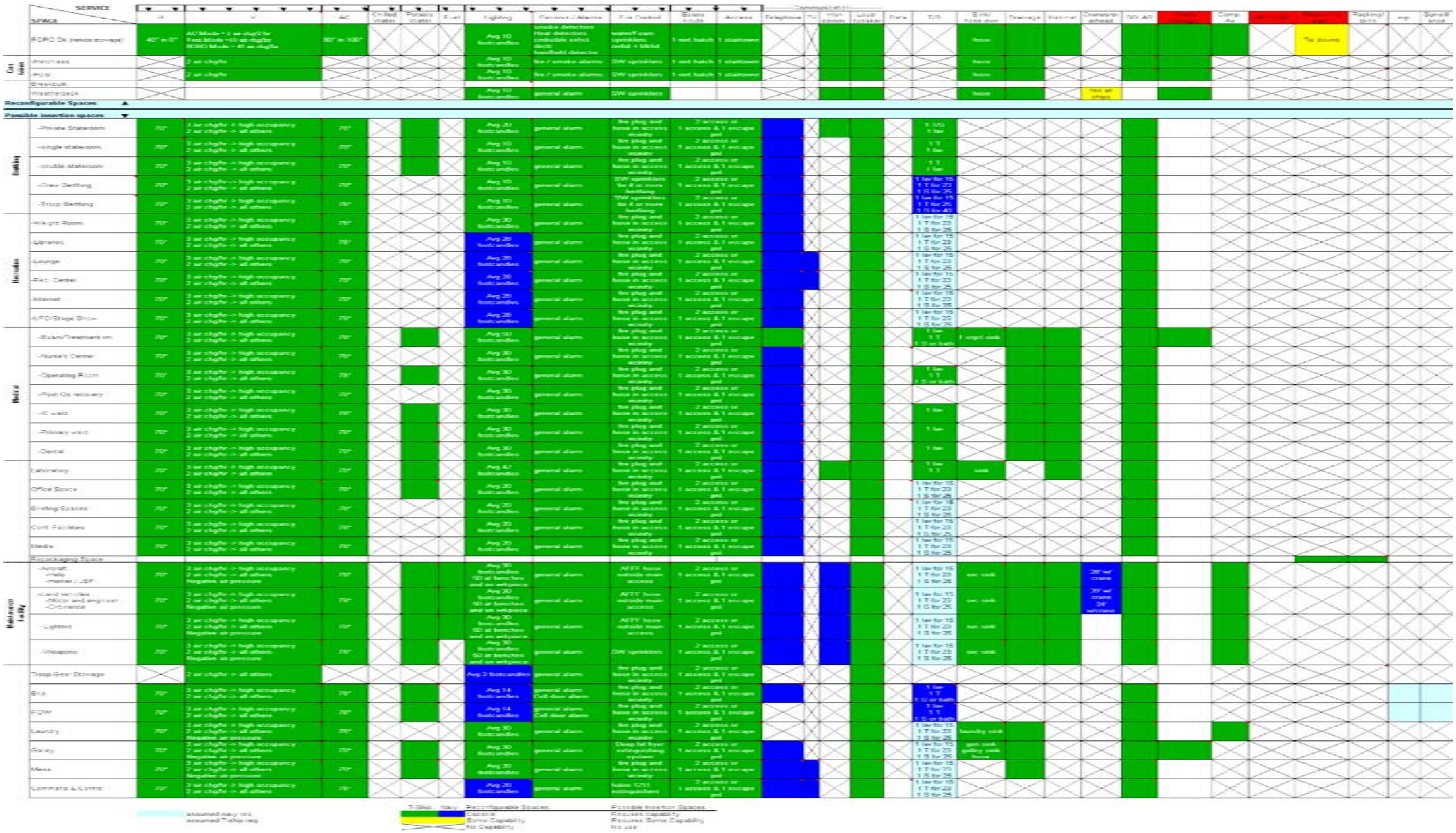

1 Full Spiral Ramp-
Deck 1-Angled
28 Large Vehicles
Vehicle Area=13,440sqft
Cargo Area=106'x485'
Deck Area= 106'x602'
Stowage Factor=22%
1 Full Spiral Ramp
Deck 2- Angled
28 Large Vehicles
Vehicle Area=13,440sqft
Cargo Area=106'x485'
Deck Area= 106'x602'
Stowage Factor=22.1%
1 Full Spiral Ramp
Deck 3- Angled
28 Large Vehicles
Vehicle Area=13,440sqft
Cargo Area=106'x485'
Deck Area= 106'x602'
Stowage Factor=22.1%
Deck Layout Showing Turning Area Required For Vehicles.
Large Trucks
Parking Lines
Turning Lanes
Spiral Ramp
Flat Deck
1 Full Spiral Ramp-3 Decks-Angled Design
84 Large Vehicles
Vehicle Area=40,320sqft
Total Cargo Area=154,230sqft
Total Deck Area=9,060sqft
Total Spiral Ramp=19,437sqft
Cargo/Deck/Spiral Area=182,727sqft
Alternate Arrangement: 1 Full Spiral Ramp
With Turning Area Required
Project: Seabasing Innovation Cell NSWC Carderock
Dimensions in Feet
Dwg No: 19
Dwg By: Amber Huffman
Date 05/27/03
Checked by: Ryan Hayleck
Date 06/05/03


2 Full Spiral Ramps/Racetrack
Deck 1
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x371'
Deck Area= 106'x527'
Stowage Factor=26.8%
Onload/
Offload
2 Full Spiral Ramps/Racetrac
Deck 1
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x371'
Deck Area= 106'x527'
Stowage Factor=26.8%
2 Full Spiral Ramps/Racetrack
Deck 1
28 Large Vehicles
Vehicle Area=40'x12'=13,440sqft
Cargo Area=106'x371'
Deck Area= 106'x527'
Stowage Factor=26.8%
Deck Layout Showing Turning Area Required For Vehicles.
Large Trucks
Parking Lines
Turning Lanes
Spiral Ramp
Flat Deck
2 Full Spiral Ramps/Racetrack-3 Decks
84 Large Vehicles
Vehicle Area=40,320sqft
Total Cargo Area=117,978sqft
Total Deck Area=Included in Cargo
Total Spiral Area=32,376sqft
Cargo/DeckSpiral Area=150,354sqft
Alternate Arrangement: 2 Full Spiral Ramps With Turning Area Required
Project: Seabasing Innovation Cell NSWC Carderock
Dimensions in Feet
Dwg No: 20
Dwg By: Amber Huffman
Date 05/27/03
Checked by: Ryan Hayleck
Date 06/05/03


2 Full Spiral Ramps
Deck 1- Angled Parking
28 Large Vehicles
Vehicle Area=13,440sqft
Cargo Area=106'x524'
Deck Area= 106'x680'
Stowage Factor=19.6%
2 Full Spiral Ramps
Deck 2- Angled Parking
28 Large Vehicles
Vehicle Area=13,440sqft
Cargo Area=106'x524'
Deck Area= 106'x680'
Stowage Factor=19.6%
2 Full Spiral Ramps
Deck 3- Angled Parking
28 Large Vehicles
Vehicle Area=13,440sqft
Cargo Area=106'x524'
Deck Area= 106'x680'
Stowage Factor=19.6%
Deck Layout Showing Turning Area Required For Vehicles.
Large Trucks
Parking Lines
Turning Lanes
Spiral Ramp
Flat Deck
2 Full Spiral Ramps/Racetrack-3 Decks-Angled Design
84 Large Vehicles
Vehicle Area=40,320sqft
Total Cargo Area=166,632sqft
Total Deck Area=Included in Cargo
Total Spiral Ramp=38,874sqft
Cargo/Deck/Spiral Area=205,506sqft
Alternate Arrangement: 2 Full Spiral Ramps With Turning Area Required
Project: Seabasing Innovation Cell NSWC Carderock
Dimensions in Feet
Dwg No: 21
Dwg By: Amber Huffman
Date 05/27/03
Checked by: Ryan Hayleck
Date 06/05/03


30.0°
145.9
73.2
63.8
R91.6008
49.3
45.0°
125.2
88.6
46.4
R91.6008
44.9
60.0°
112.6
97.5
16.4
R38.2
28.2
75.0°
103.5
99.9
34.9
R91.6008
77.1
90.0°
40.5
33.6
R91.6008
85.9
B
C
A
D
Proof of Angles
Project: Seabasing Innovation Cell NSWC Carderock
Dimensions in Feet
Dwg No: 22
Dwg By: Amber Huffman
Date 05/27/03
Checked by: Ryan Hayleck
Date 06/09/03

## Annex X - Re-configurable Spaces Matrix



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